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Digital Water Resources Data for Georgia

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The U.S. Geological Survey (USGS), Georgia District, in cooperation with federal, state, and local agencies has revised the Georgia Surface-Water Annual Data Report, previously published as a paper report, to a new, more informative and functional format on CD-ROM. The new format is based on a geographic information system (GIS) user interface that allows the user to view map locations of the hydrologic monitoring stations and networks within their respective basins.

Several methods are provided for users to easily search for and retrieve data on stations. Graphical summaries of the current water year and selected historical data illustrate seasonal and annual stream characteristics. Users can view or print out site information and data tables in the traditional paper report format, or download data for their use with other applications.

This digital data report includes the annual surface water data that has historically been published as a paper report. The CD-ROM, Georgia Surface-Water Annual Data Report, adds more functionality for the user, including graphical views of the data, digital files of data sets from each gaging station, a site location map, and photography at selected station locations. These options for a streamflow (discharge) station are shown in figure 1. The CD-ROM also contains user-friendly help and examples.

The first page of the station summary (figure 2) gives the user a graphical summary of the selected streamflow station. An annual hydrograph, a graph of historic monthly statistics (maximum, minimum and mean), a graph of annual mean streamflow, a graph of annual peakflows, a site location map, and a photograph are included for most sites. The summary file is comprised of a station manuscript, which contains descriptive information, period of record, location, historical extremes, record accuracy and comments, as well as annual data tables of daily records, monthly statistics, and period-of-record statistics.

The data sets contained on this CD-ROM include the stage and streamflow from all continuous and non-continuous gaging stations for the 1999 water year. All continuous water-quality monitoring data sets also are included in this release. Discrete water-quality sampling sites and continuous ground-water-level monitoring wells are shown as network data layers; however no measurement data are included on this CD-ROM.

The year 2000 report will contain all USGS water resources data for Georgia, including water quality and ground-water measurements. Delineations of the watersheds at selected surface-water stations will be included. Also, several useful tools will be added, including searching for sites at a specified radius, a measurement tool, and the display of latitude-longitude at any point on the GIS user interface.

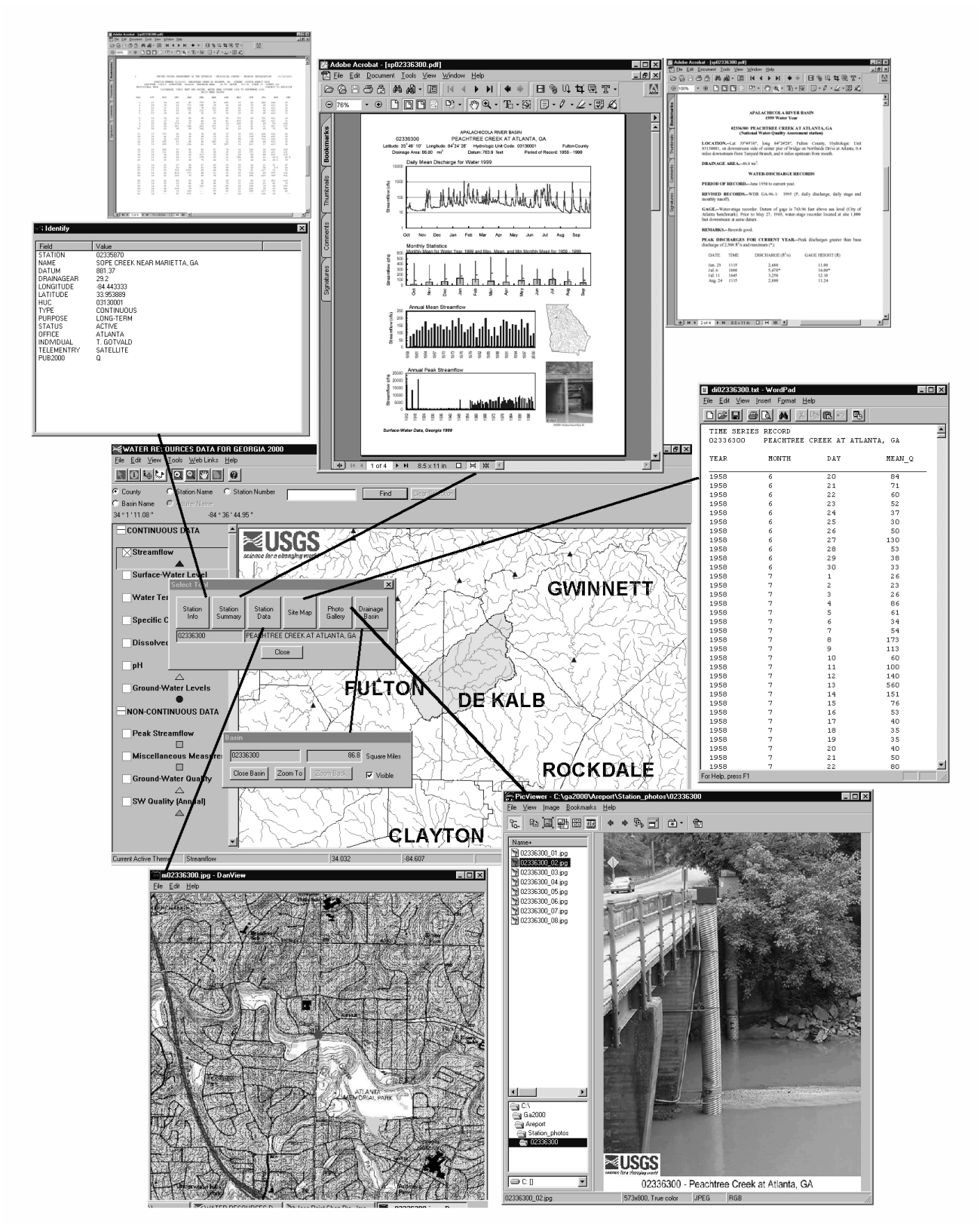

Figure 1. Options for a selected streamflow (discharge) station.

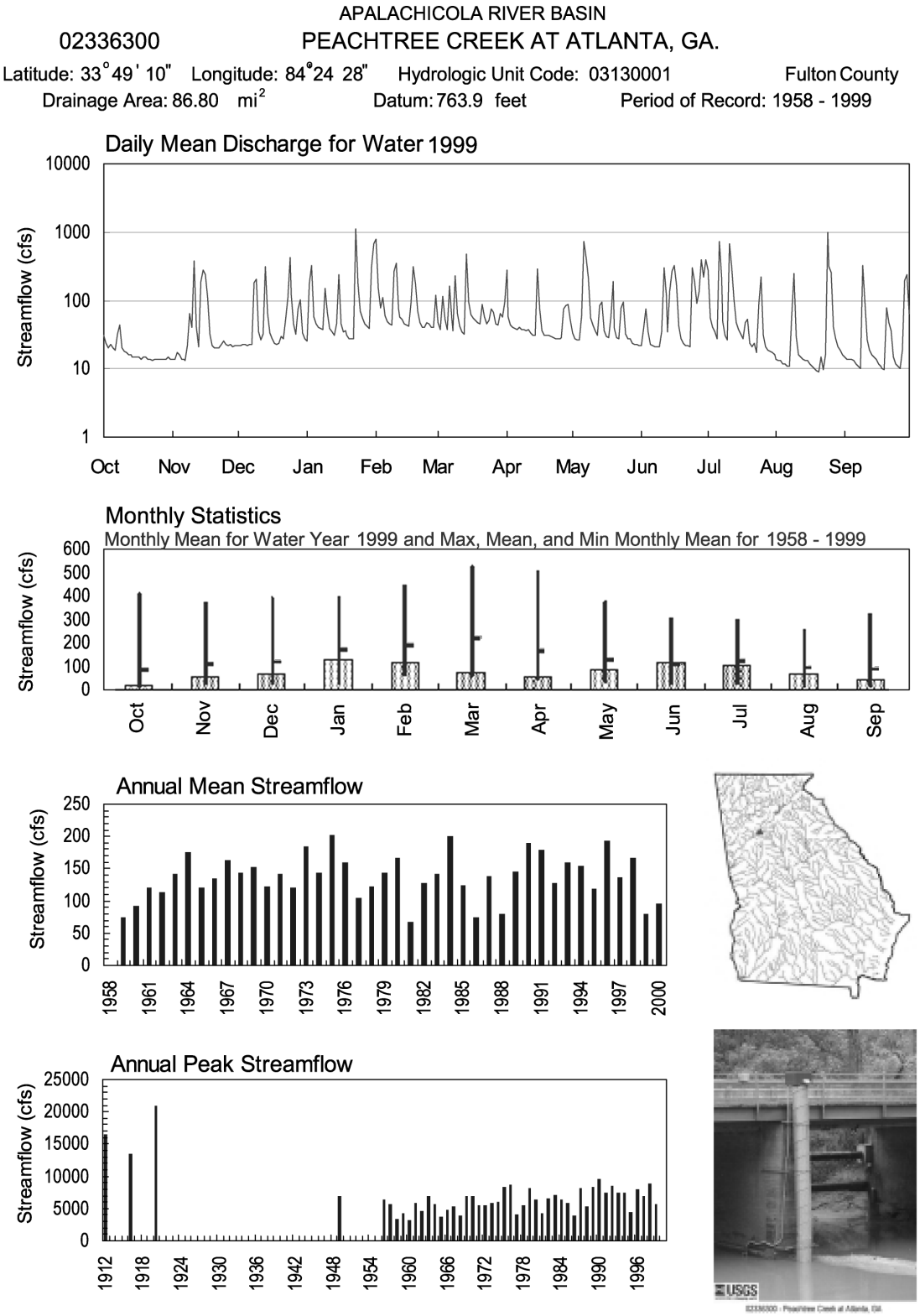

Figure 2. Graphical summary page for Peachtree Creek at Atlanta.

Using the Digital Environmental Atlas of Georgia for Natural Resource Investigations

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ABSTRACT

The U.S. Geological Survey (USGS) and Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey recently released (2000, updated and re-released in 2001) a two-volume Compact Disc (CD) set entitled "Digital Environmental Atlas of Georgia" (Atlas) containing computer readable data sets for geographic information systems (GIS). The Atlas not only provides a wide range of traditional maps, but also enables users to experiment with their own individually created maps through personal-computer-based GIS software included on the CDs. The information on the CD set will help Georgia's students learn more about their state and will be useful to businesses and various local, State and Federal agencies.

The CDs contain 38 digital map data sets covering the State of Georgia that are useful to the general public, private industry, schools, and government agencies. The data sets include: Towns and Cities, Public Lands, State Parks, Trails and Greenways, County Boundaries, Geographic Names, Hydrologic Units, Shorelines, Soils, Major Roads, Public Airports, River Reach - Major Streams, Roads, Ground-Water Site Inventory, Hydrography, 7.5-Minute Topographic Quadrangle Index, Surface-Water Monitoring Stations, Elevation Contours, 1:250,000-scale Digital Elevation Model, 1:100,000-scale Digital Raster Graphic, 1:250,000-scale Digital Raster Graphic, 1:500,000-scale Digital Raster Graphic, Land Cover, Land Use, Pipelines, Transmission Lines and Miscellaneous Transportation, Railroads, River Corridors with Mean-Annual Streamflow Greater than Four Hundred Cubic Feet Per Second, 1:250,000-scale Slope, National Forests, Physiographic Provinces, Surficial Geology, Ground-Water Pollution Susceptibility, Most Significant Ground-Water Recharge Areas, and the Georgia Department of Transportation State Highway Map.

ArcExplorer® Version 1.1 software, by Environmental Systems Research Institute, Inc.[2], is included on the CDs. ArcExplorer allows the user to display combinations of data sets and attributes using selected colors and patterns. Spatial and logical queries also can be performed to locate selected sets of attributes. ArcExplorer gives the user the ability to perform the following spatial functions using the data sets on the CDs:

- Overlay multiple data sets
- Identify data set features
- Find and locate features using data set attributes
- Query the data sets using Boolean logic
- Create tables of selected data set features
- Create custom maps for use in reports
- Measure areas and distances within data sets

Three examples of these capabilities are illustrated below. The included ArcExplorer GIS interface depicting user-selected spatial data is shown in figure 1. The results from a query of residential landuse by county (DeKalb) is shown in figure 2. Both tabular and graphical results are displayed. A schist mica/gniess/amphibolite geologic formation in the vicinity of Stone Mountain, over a 1:100,000-Scale topographic map of the area is shown in figure 3. Additional examples depicting a variety of uses for the data covering the functionalities listed above are included on the CD.

Additional GIS information for Georgia may be accessed through the USGS website for Georgia at http://ga.water.usgs.gov or on the Georgia Department of Natural Resources website at http://www.dnr.state.ga.us. Similar information products are being made available by the Georgia GIS Clearinghouse (with active participation from a number of Federal and State and local agencies), website at http://www.gis.state.ga.us.

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[2] Any use of trade names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government

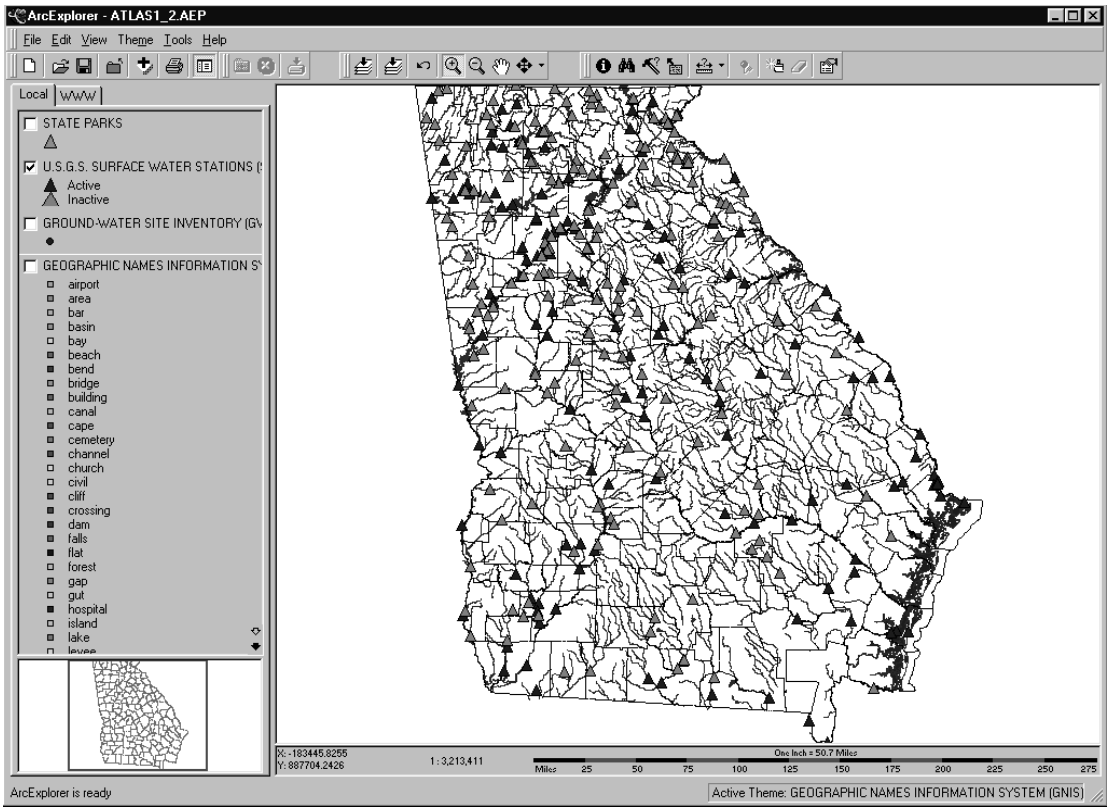

Figure 1. ArcExplorer GIS interface to the Digital Environmental Atlas of Georgia.

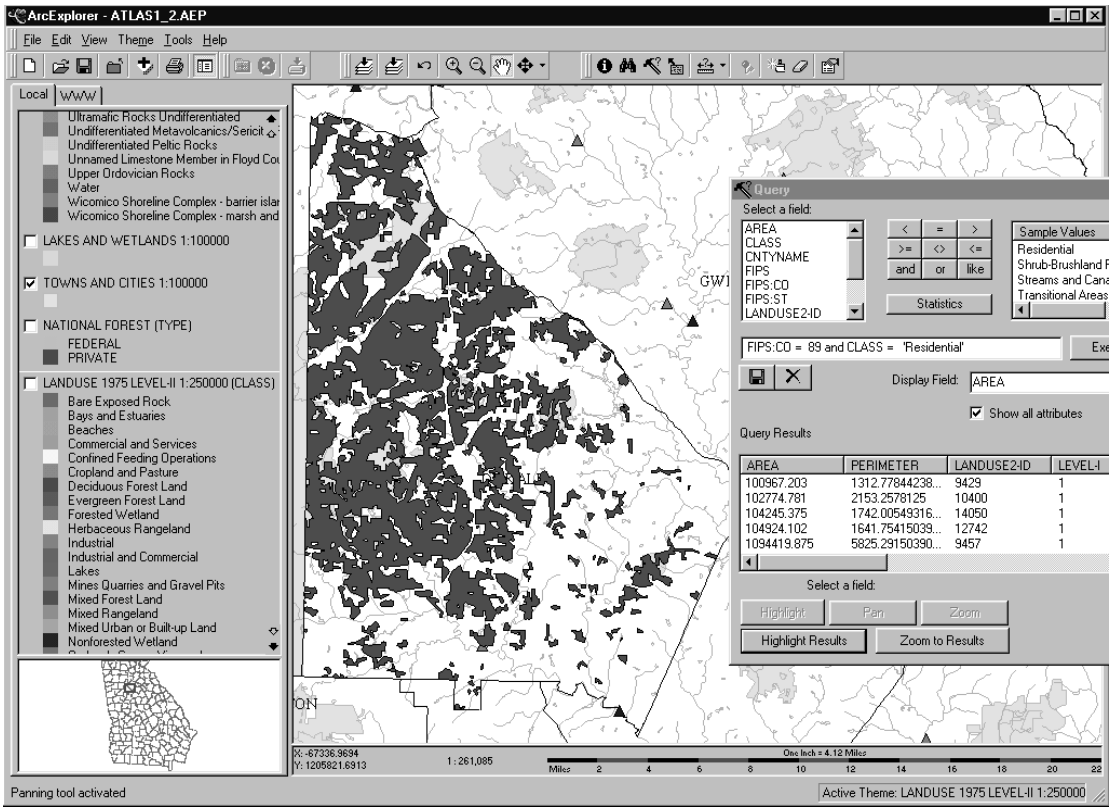

Figure 2. Selection and display of residential landuse by selected county (DeKalb).

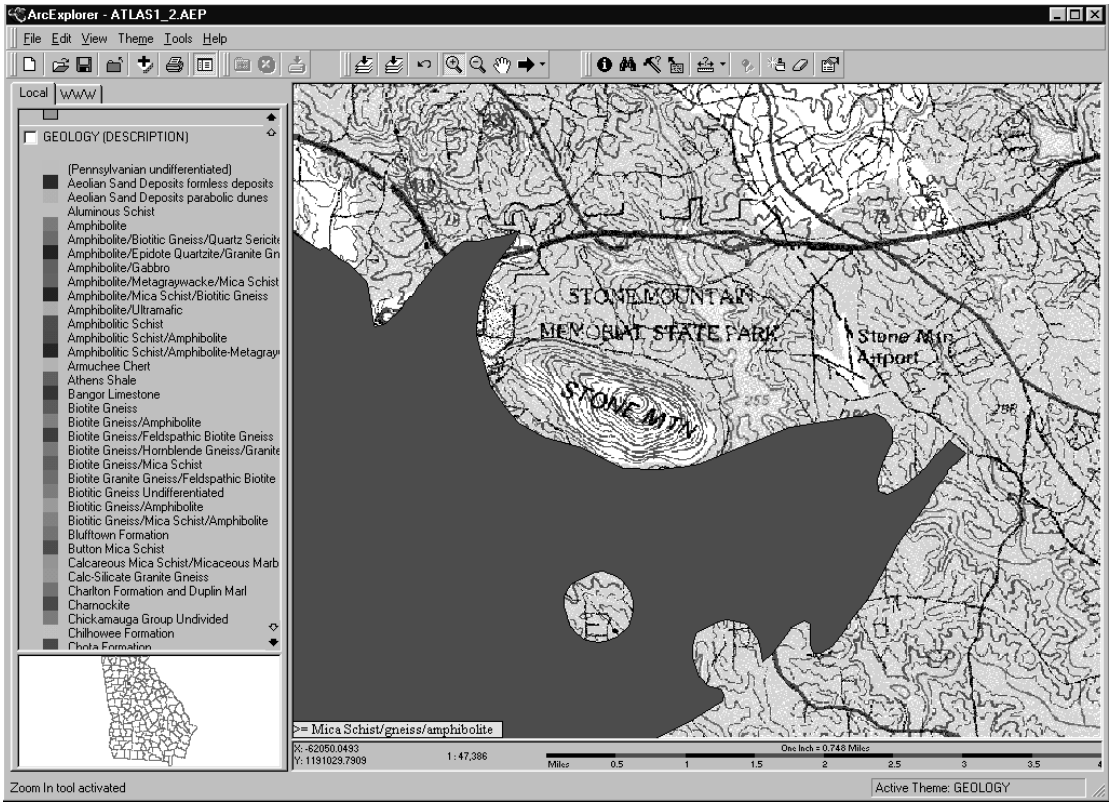

Figure 3. Mica schist/gneiss/amphibolite geologic formation in the vicinity of Stone Mountain, Georgia.

Characterizing the Fractured Crystalline-Bedrock Aquifers of North Carolina—A Federal and State Cooperative Study

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To address concerns regarding the potential for contamination of ground water in fractured crystalline-bedrock aquifers of the Piedmont and Blue Ridge provinces of North Carolina, the U.S. Geological Survey (USGS) initiated in 2000 a multiyear study with the North Carolina Department of Environment and Natural Resources, Division of Water Quality. Overall goals of the study include the characterization of ground-water flow systems at selected type-area study sites that are representative of broader hydrogeologic terranes and the identification of natural hydrologic and geologic controls that influence ground-water quality, availability, and transport. In most settings, conceptually the aquifer is a three-part system, consisting of fractured crystalline bedrock overlain by regolith, and a transition zone intermediate between unweathered bedrock and weathered regolith. The regolith-bedrock transition zone is a zone of relatively high transmissivity within the three-part system.

Type-area investigations are planned at six study sites within the Piedmont and Blue Ridge physiographic provinces in North Carolina. The study sites may range in size from a few acres to as large as a 16-square-mile watershed, depending on the research objectives. Soil and rock cores collected at each study area are being examined for features that may affect ground-water quality and movement. Borehole geophysical logs and cores are being used to describe the subsurface hydrogeologic setting, including lithology, foliation orientation, fracture occurrence and orientation, and flow characteristics. Surface resistivity surveys are being conducted to characterize the near-surface hydrogeology in areas between wells and surrounding areas that have no subsurface information. Two-dimensional surface resistivity methods are being used to determine depth to bedrock, characteristics of the overlying regolith and transition zone (collinear electrode arrangement), and to determine the presence or absence of directional bedrock anisotropy (square array electrode arrangement) related to steep fracturing.

Wells are being installed in clusters along transects in order to characterize flowpaths, hydraulic gradients, and water-level fluctuations. Aquifer tests and water-quality analyses at these study sites will contribute information on the hydrologic characteristics of the geologic units along the transects. Tracer tests and ground-water dating techniques will be used to estimate time-of-travel and to delineate flowpaths in the ground-water system. Analyses of major ions will be used to examine rock and water interactions and geochemical processes within each hydrogeologic terrane. Surface-water samples from study sites having lakes or streams will be analyzed to evaluate ground-water and surface-water interactions.

To date (July 2001), type-area investigations have begun at five of the six selected study sites, here described as the Langtree, Lake Wheeler, Reidsville, Bent Creek, and Cullasaja study sites. In the central Piedmont, 30 wells have been drilled at the 20-acre Langtree Peninsula study area on Lake Norman (Davidson College recreational facility campus) in Iredell County. Studies will address relations between ground water of the peninsula and surface water of Lake Norman. Weakly-foliated quartz diorite is the primary rock type, and is typical of the Charlotte Belt. Fractures generally are sparse and the regolith-bedrock transition zone thickness is variable. Six coreholes were drilled to collect samples of the regolith and bedrock, and to determine depth and thickness of the transition zone. Well installations at the Langtree study area include: 6 well clusters consisting of 3 wells each that tap the regolith, transition zone, and bedrock for determining vertical gradients and water-quality variation between permeable zones; and 12 shallow regolith wells for measuring variation in shallow ground-water flow directions. These wells were installed at selected locations along two down-slope transects. Also, a suite of borehole

geophysical logs has been collected from each bedrock well for the purpose of lithologic and fracture characterization, including caliper, resistivity, natural gamma, fluid, acoustic and optical televiewer, and flowmeter logs. Real-time continuous ground-water-level data from well cluster MW-2 are available online at http://water.usgs.gov/nc/. Core drilling either has been completed or is ongoing at two other research sites.

At the Lake Wheeler study area in the eastern Piedmont (North Carolina State University (NCSU) research farm) in Wake County, geologic coring and well installation is complete. The primary rock type is the Raleigh gneiss, a fairly homogeneous quartzo-feldspathic gneiss on the west flank of the Raleigh metamorphic belt. Three clusters of observation wells were drilled containing three or four wells each that tap the regolith, transition zone (1-2 wells), and bedrock. In addition, a fourth bedrock well was installed for testing the hydraulic properties of the bedrock aquifer. Two additional shallow regolith piezometers were drilled near the proposed bedrock pumping well. Borehole geophysical logs also have been collected at the Lake Wheeler study area for subsurface lithologic and fracture characterization. The accessibility of the Lake Wheeler study area, near the North Carolina District office, makes it well suited for training and testing of equipment. Two-dimensional surface resistivity surveys were conducted at the Lake Wheeler study area and at a third research study area near Reidsville, discussed below.

The Reidsville study area in the western Piedmont encompasses the upper Wolf Creek watershed (about 16 square miles), in Rockingham County. Geologic mapping of this area in progress as part of the USGS Geologic Division Bedrock Regional Aquifer Systematics Study (BRASS) project. The Reidsville map area contains the NCSU Upper Piedmont Research Station where core drilling has been conducted. Well-foliated metasedimentary and metavolcanic rocks and felsic-to-mafic metamorphosed intrusive rocks in this area have varied compositions, as well as gentle to moderate dips complicated by folding, and are typical of the Milton belt in the western Piedmont. The rocks are highly fractured, having abundant low-angle fractures parallel to foliation, intersected by steeply dipping fractures. The regolith-bedrock transition is characterized by interlayering of rock types that weather differently. Data will be collected from well transects along a dip slope and cut slope to evaluate the potential controls of fractures parallel to foliation on ground-water flow paths and ages.

Coring is ongoing at the fourth research site in the Bent Creek Demonstration Forest (U.S. Forest Service) in Buncombe County (Blue Ridge Province). Detailed geologic mapping of the watershed was conducted by the North Carolina Geological Survey. The major group of rocks in that area are designated as part of the Ashe formation. Well installations similar to the Langtree and Lake Wheeler study sites are planned for Reidsville and Bent Creek.

Two additional type-area study sites are planned for the North Carolina Piedmont and Blue Ridge Ground-Water Study. Detailed geologic mapping is being conducted under the USGS Geologic Discipline BRASS project at a fifth research study area in the Cullasaja watershed in Macon County (Blue Ridge Province). The rapidly developing Cullasaja study area will be compared with the more pristine hydrologic environment of the Bent Creek watershed study area; both watersheds have similar bedrock geologic settings, being designated as part of the Ashe formation. A sixth study area also has been selected at an NCSU research farm near Asheville in Henderson County (Blue Ridge Province).

Arsenic Is Ubiquitous but not Elevated in Abandoned Coal-Mine Discharges in Pennsylvania

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Despite elevated concentrations in coal beds, dissolved As rarely is elevated in abandoned coal-mine discharges in Pennsylvania. For 140 samples collected in 1999, concentrations of As ranged from <0.03 to 15 μg/L in 41 anthracite mine discharges and from 0.10 to 64 μg/L in 99 bituminous coal-mine discharges (table 1). The pH of these discharges ranged from 2.7 to 7.3, with dominant modes at pH 3-4 and 6-7; concentrations of Fe ranged from 46 to 512,000 μg/L. The As was positively correlated with pH, alkalinity, Fe, SO_4, Cl, Br, and I and was inversely correlated with redox potential. Aqueous speciation computations indicated arsenate species ($H_2AsO_4^-$ and $HAsO_4^{2-}$) predominated.

Concentrations of As in Fe-rich precipitate (ochre) samples from 20 of the anthracite discharge sites ranged from <0.07 to 270 mg/kg. Generally, the concentration of As in the solids was positively correlated with the concentration of As and pH of the source water; the ratio of As concentrations in solution to As in solids (Kd) did not vary with pH. This trend could indicate increased capacity for attenuation of As by Fe compounds at higher pH. Poorly crystalline Fe(III) oxyhydroxides, such as ferrihydrite, tend to form under near-neutral conditions whereas Fe(III) oxyhydroxysulfates, such as schwertmannite, and crystalline Fe(III) oxyhydroxides, such as goethite, are predominant Fe(III) phases formed at low pH. Ferrihydrite could have greater sorption capacity for arsenate than goethite or schwertmannite. Nevertheless, the As that is associated with metastable Fe(III) compounds, such as ferrihydrite and schwertmannite, can be remobilized (1) upon conversion of metastable compounds to more stable phases such as goethite or (2) from reductive dissolution or acidic digestion.

Table 1: Composition of discharges from abandoned coal mines in Pennsylvania, 1999

[median(minimum-maximum)]

Coalfield & number of samples	pH	Redox Potential (mV)	Oxygen	Sulfate	Iron	Manganese	Arsenic
			(mg/L)				(μg/L)
Anthracite N=41	5.1 (3.0-6.3)	390 (170-770)	1.9 (0.3-11.1)	260 (36-1300)	15 (0.046-312)	2.9 (0.019-19)	0.62 (<0.03-15)
Bituminous N=99	5.2 (2.7-7.3)	340 (140-800)	.6 (0.2-11.5)	580 (120-2000)	43 (0.16-512)	2.3 (0.12-74)	2.0 (0.1-64)

Ground-Water Exploration and Development in Igneous and Metamorphic Rocks: Part I—Influencing Factors and Considerations

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Exploration for and development of ground water in deformed igneous and metamorphic rocks in regions having a sub-tropical weathering environment are poorly understood because few studies have been conducted. Much of the funded research and many of the recent and current studies in this regard seem to focus on the physics of ground-water movement in fractured rock. During the last several decades these studies were driven by environmental containment and remediation problems and concerns. The objectives and goals of these environmental assessments differ from those required for exploration and development of water as a resource. For these programs, assessment of quantity, quality, and sustainability of the resource are of utmost importance.

Thirty-five years experience in the exploration and development of ground-water resources in igneous and metamorphic rocks of the southeastern United States has convinced the authors that, among the many factors that influence ground water in these rocks, the single most important factor is rock type. Rock type directly influences all other characteristics, including: reaction to physical and chemical stresses, type of weathering, depth of weathering, and topography. Without knowing the detailed geology of an area/site, all other factors influencing ground water lack a full and meaningful context.

To successfully explore and develop ground water in igneous and metamorphic rocks, an understanding of physical characteristics controlling ground-water movement is necessary. The interrelations, both inherent and spatial, of rock type, structure, type and depth of weathering, and topography must be known and understood. Each of these variables has numerous significant variations. Because these variations and the influence of each of these variables on ground water is relative rather than absolute, it becomes obvious that ground-water exploration and development in metamorphic and igneous rocks must be conducted on a site-specific scale.

The exploration and development approach proposed here begins with detailed site-specific geologic mapping at a scale of 1:24,000 or smaller to identify rock types. The mapping should be detailed enough to form an understanding of the major lithologic units and the structural features in the area. It is important to note any observable discontinuities in the rock—such as compositional differences (layering) and fractures (joints and/or faults). Topography and type of weathering must also be noted and taken into consideration in relation to the nature and extent of the recharge area. Lastly, the spatial relations of rock types and discontinuities to topography, type and depth of weathering, and recharge area are considered.

Though rarely of sufficient detail for siting water-well drilling locations, 1:24,000-scale geologic maps serve as an excellent beginning for more detailed study and analysis. Without such maps, geologists unfamiliar with the area of interest must spend a tremendous amount of time just getting familiar with mappable lithologic units. For this and many other reasons, it is important that efforts to conduct 1:24,000-scale geologic mapping by experienced qualified geologists in organizations such as the U.S. Geological Survey, state geological surveys, and universities continue.

Cytology of the Pallid Sturgeon Sperm Cell

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The pallid sturgeon (*Scaphirhynchus albus*) is now restricted to large rivers of the central United States, primarily the Missouri and Mississippi River Drainages (Lee et al. 1980; Keenlyne et al. 1994). Until recognized as a separate species, it was mistakenly identified as the shovelnose sturgeon (*S. platorhynchus*) (Carlson et al. 1985; Etnier and Starnes 1993). This confusion left us very little regarding its early history and distribution (Etnier and Starnes 1993), and we contend that it is likely that the pallid sturgeon was once sympatric with the shovelnose sturgeon throughout much of its traditional range, which once included west slope Appalachian rivers. Many anthropomorphic effects have contributed to the very limited ranges of both these sturgeons. These include impoundments, pollution, channelization, and other habitat degradation.

The pallid sturgeon is listed as an endangered species in the U.S. by the Fish and Wildlife Service (UFWS)(Kallemeyn 1983). Both general (Booker et al. 1993; Pavlov 1993) and specific strategies or recovery plans (U.S. Fish & Wildlife Service 1992) call for the development of cryopreservation (cp) sperm banks to aid in the preservation of genetic biodiversity, ultimately leading to artificial propagation for recovery stockings in areas of extirpation (Booker et al. 1993). Sperm cell cytology descriptions will provide researchers with guidance regarding choice of cp method development (Stoss 1983; Leung and Jamieson 1991) and will provide a normal reference cell for comparison following the exposure of the rare sperm cells to the harsh liquid nitrogen cp temperatures (Lahnsteiner et al 1992; Lin et al. 1996). In addition, the structure of biological organisms are always an adaptation to function (DeRobertis and DeRobertis 1980), and such biological structures may provide important clues to aid in uncovering important life history mysteries (DeJong-Moreau et al. 2000).

Pallid sturgeon sperm cells were taken from five mature males at the UFWS Gavins Point National Fish Hatchery, Yankton, South Dakota. Briefly, cells were fixed in in fresh 2.5% paraformaldehyde plus1.5% glutaraldehyde in 0.2M sodium cacodylate buffer at pH 7.4. Sperm cell cytology and morphology were examined using JEOL 1200 EXII EXII transmission, and JSM 5400 scanning electron microscopes, respectively. This was performed at the Pennsylvania State University Electron Microscopy Facility (University Park, PA). Line drawings from other sturgeon species were performed to scale using digital caliper measurements from photomicrographs within respective cited references (DiLauro et al. 2001).

The sperm cell of this endangered species was similar to those of nearly all other described sturgeon sperm cells (Cherr and Clark 1984; DiLauro et al. 1999;2000;2001), which all share a gradual decreasing taper of the nuclear diameter from posterior to anterior, with the exception of the Atlantic sturgeon (DiLauro et al. 1998). Mean length of the radially symetrical palid sturgeon sperm cell body (acrosome + nucleus, i.e. head + midpiece) was approximately 6 μm, and the length of the flagellum was about 37 μm, resulting in a total cell length of about 43 μm. The pallid sturgeon sperm cell is intermediate in size between those of the Chinese and Atlantic sturgeons (Xu and Xiong 1988; DiLauro et al. 2001), however, resembles that of the lake sturgeon (DiLauro et al 2000) more closely in shape, but is shorter in overall length than that of the latter. The pallid sturgeon sperm cell differs from those of other sturgeons chiefly in the acrosomal area, with the posterolateral projections (PLP) being shaped like acute triangles. The PLP are also situated in a spiral arrangement about the longitudinal axis of the cell, and are much longer than those of other sturgeons studied. The acrosomal shape in cross-section also appears more like a hollowed-out cone than that of an acorn cap from an oak tree, as in other sturgeon previously studied. In

addition, we were able to confirm the structural arrangement in the distal centriole as being composed of nine sets of microtubular triplets arranged about the periphery of the centriole, identical to the arrangement in the proximal centriole. We were not able to confirm this distal centriole arrangement in earlier studies with other species (DiLauro et al. 1998; 1999; 2000).

This information will be of use to researchers involved with cp method development. It will also be of potential use to fishery biologists, forensic biologists, zoologists, geneticists, reproductive physiologists, taxonomists, evolutionary biologists, and aquaculturists.

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Cytology of the Lake Sturgeon Sperm Cell

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The lake sturgeon (*Acipenser fulvescens*) historically inhabited freshwater rivers, lakes and large streams from Canada southward to northern Alabama, bounded on the east by the Appalachian mountains, with the western U.S. range less accurately defined. Although some stable populations of lake sturgeon exist in Wisconsin and in some areas of Canada, it is either extirpated or depleted in most of its traditional range. The lake sturgeon is known to have thrived in most west-slope Appalachian rivers. A few mature lake sturgeon have been found in western Appalachian reservoirs in the last 30-40 years as obvious vestiges of older populations, as no evidence of recent recruitment exists for those waters (Trautman 1981; Etnier and Starnes 1993). The lake sturgeon is listed as vulnerable to extinction (IUCN 1988; Campbell 1993) and as threatened by the American Fisheries Society (Williams et al. 1989). Despite protected status, migratory spawning routes to critical habitat continue to be blocked by impoundments, and critical habitat is disrupted or destroyed by other human intervention, leading to further losses in presently indigenous areas (LaHaye et al. 1992; Auer 1996).

Restoration plans in areas of extinction include sperm cryopreservation (cp) method development, which is recommended to preserve genetic biodiversity and allow for readily-available sperm in storage until fecund females are captured (Booker et al. 1993). Sperm cell morphology description will provide researchers guidance regarding methods of choice (Stoss 1983; Leung and Jamieson 1991) and provides normal cell description for comparison following exposure of cells to the harsh environment of cp (Lahnsteiner et al. 1992; Lin et al. 1996). In addition, structure of biological organisms are always an adaptation to function (DeRobertis and DeRobertis 1980), therefore biological structure will provide keys to unraveling life history information (DeJong-Moreau et al. 2000). Objectives were to describe the cytology of the lake sturgeon sperm cell.

Lake sturgeon sperm cells were collected from five mature males captured in the Des Prairies River near Laval, Quebec Canada. Briefly, cells were fixed in in fresh 2.5% paraformaldehyde plus 1.5% glutaraldehyde in 0.2M sodium cacodylate buffer at pH 7.4. Sperm cell cytology and morphology were examined using JEOL 1200 EXII transmission, and JSM 5400 scanning electron microscopes, respectively. This was performed at the Pennsylvania State University Electron Microscopy Facility (University Park, PA).. Line drawings from other sturgeon species were performed using digital caliper measurements from photomicrographs (DiLauro et al. 2000).

The cells of this depleted species had a distinct acrosome, a defined nucleus (head) region, a midpiece and a single flagellum. Sperm cells of this species exhibit radial symmetry, an elongate shape, and the presence of three endonuclear canals, similar to those of other sturgeons (DiLauro et al. 1999). The length of the lake sturgeon cell body (acrosome + nucleus + midpiece) is about 7 μm, and the length of the flagellum is 50 μm, resulting in a total cell length of 57 μm. Although slightly smaller in total length and width than the shortnose sturgeon sperm cell, that of the lake sturgeon is similar in cytology, overall size and shape. It shares a similarity in shape with all others compared with the exception of the Atlantic sturgeon sperm cell, which tapers decreasingly from head to tail in nuclear (head) width. The lake sturgeon sperm cell also has longer posterolateral projections than those of the Atlantic and shortnose sturgeon sperm cells (DiLauro et al. 1998; 1999). Our results suggest a more recent evolutionary linkage between the lake and shortnose sturgeons than with the Atlantic sturgeon. This work represents the first ultrastructural description of the lake sturgeon sperm cell and should have applications in cp restoration efforts involving this species. This information should be of potential use in the areas of fishery biology, forensics, zoology, reproductive physiology, taxonomy, evolutionary biology, and aquaculture.

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Geochemical, Mineralogical, and Environmental Characteristics of Metamorphosed Black Shales of the Central Appalachians, with Comparisons to Metalliferous Shales of the Northern Appalachians

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ABSTRACT

Primary geochemical features of metamorphosed black shales that occur throughout the Central and Northern Appalachian regions reflect their original depositional environments, despite mineralogical reactions as a result of regional metamorphism and weathering. Near-surface reactions of sulfide minerals and water in these black shales causes acid drainage and the release of potentially toxic trace elements such as arsenic, copper, manganese, and mercury. High and anomalous contents of these elements represent pervasive and challenging problems associated with many rivers and streams in the Eastern United States. Acid rock drainage occurs naturally and is not associated with human activities. Simple weathering of rocks that host low-grade occurrences of iron sulfide minerals, for example, sedimentary pyrite layers in black shales is enough to pose potentially significant acid drainage problems. Release of potentially toxic trace elements such as arsenic, copper, manganese, and mercury that are either present as minute sulfide or sulfosalt mineral inclusions or structurally bound as trace elements in the lattice of the host sulfide minerals can also result in significant environmental impacts on surface and ground waters.

We have studied various shales (or their metamorphic equivalents) in the Central Appalachians to evaluate the potential for acid drainage and the release of toxic metals. Sulfidic and graphitic schists of Cambrian age that include the Anakeesta Formation (fig. 1) constitute part of the bedrock of the Great Smoky Mountains National Park (GSMNP). Metamorphosed sedimentary rocks of the Ocoee Supergroup that range in age from 545 million to 1 billion year old dominate the bedrock geology of the GSMNP (Schultz, 1998; Southworth, 1995; King and theirs, 1964). Rocks of the Snow Bird Group, Cades Sandstone, Rich Butte Sandstone, and rocks of the Great Smoky Group, which include Elkmont Sandstone, Thunderhead Sandstone, Anakeesta Formation, Copper Hill Formation, and Wehutty Formation, also underlie most of the park (Southworth, 1995). Carbonate rocks of the Ordovician Jonesboro Formation are exposed in the western end of the park near the Cades Cove area. This package of rocks comprises a number of blocks that are bound by faults that dip shallowly to the southeast (Southworth, 1995). These rocks have been metamorphosed to varying degrees by successive tectonic events throughout the Paleozoic.

The Anakeesta, Copper Hill, and Wehutty Formations are metamorphosed shaly rocks that contain trace to locally minor amounts of pyrite and pyrrhotite and graphitic organic matter, which imparts a black color to carbonaceous parts of the rocks. The ancient environment on the ocean floor where these sediments were deposited was anoxic (oxygen-poor) which promoted the accumulation of organic matter and the formation of pyrite in the sediments. Within the boundary of the Great Smoky Mountains National Park, copper-rich massive sulfide deposits hosted by shaly portions of the Copper Hill Formation occur at the Fontana and Hazel Creek mines (Robinson and others, 1992). Ground and surface waters draining the mines have elevated acidity and heavy-metal contents relative to waters draining sandstone or carbonate rocks in the GSMNP (Seal and others, 1998, 2000). Studies of secondary sulfate minerals associated with acid mine drainage in the Park has demonstrated that salt dissolution contributes to metal loadings and acidity in the surface waters and causes short-term perturbations in water quality

(Hammarstom and others, 2000). The U. S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), has initiated a study of factors that affect water quality associated with the abandoned Fontana and Hazel Creek mines in Great Smoky Mountains National Park. An important aspect of evaluating the local impact of acid mine drainage is establishing the contributions from natural weathering of bedrock. The current climatic environment of the park is that of a humid temperate subtropical rainforest and the rocks are subjected to warm-to-sub-freezing temperatures. At the present time, thin layers of regolith develop on the shaly units in the park and during periods of high rainfall these have historically resulted in debris flows on the steep slopes underlain by the units (Schultz, 1998). The surface area exposure of fresh rock during debris flows serves to enhance naturally the rate of generation of acid from these rocks. Thus, weathering of iron sulfide minerals from shales and their metamorphosed equivalents by modern ground and surface waters is potentially a significant source of acid pollution in small creeks and streams throughout the Great Smoky Mountains National Park.

Diagnostic geochemical signatures (e.g., rare earth element, Ga, high-field strength elements) of shales in the Central Appalachians (e.g., Anakeesta Formation) are preserved even though the rocks have undergone regional metamorphism and weathering. Key geochemical features distinguish critical meta-shale units or sub-units within more variable geologic formations and can be used to establish mass gains and losses for the bulk shale compositions. This information is necessary to assess the rate and amounts of natural decomposition and contributions to the near-surface environment. For example, rare earth element distributions and patterns of the meta-shales fall into two distinct subgroups when compared to average North American shale compositions (NASC). Aluminum, Ga, and the high-field strength elements also appear to be immobile under these conditions of alteration. In contrast, many of the alkali elements and metals were highly mobile during regional metamorphism and subsequent weathering of the shale. The occurrence and distribution of iron sulfide minerals and patterns of sulfidation and oxidation in weathering of the Anakeesta Formation attest to the presence and distribution of regional sources of acid and metals (Fe, Cu). Mineralogical reactions that resulted from metamorphic overprinting and subsequent weathering of metal-bearing sulfide minerals (e.g., pyrite, pyrrhotite, marcasite, chalcopyrite) have generated and continue to generate a variety of intermediate and final alteration minerals of varying stabilities (e.g., bird's-eye pyrite and marcasite, covellite, colloform hematite, goethite, ferrihydrite, and amorphous $Fe(OH)_3$, Cu-oxyhydroxides, Cu-sulfate minerals, and Mn-hydroxides). Identification and characterization of primary, intermediate and final products of the reactions yield data that are useful for establishing lithologic-to-hydrologic pathways for the release of environmentally sensitive elements (H^+, Cu, Mn, As, Se, Hg, etc.). Geochemical and mineralogical modeling studies are now being employed to understand weathering rates and how their associated geochemical processes affect acid generation and metal release from sulfide-bearing portions of the Anakeesta Formation.

Mineralogical and geochemical comparisons (table 1) can be made between shales of the Central Appalachians (e.g., Anakeesta Formation) and black shales of the Northern Appalachians (e.g., Silurian Smalls Falls Formation: Guidotti and Van Baalen, 1999; Ordovician Penobscot Formation: Stewart, 1998; Robinson and others, 2000, Ayuso and others, 2001) and average North American and black shale compositions (e.g., Vine and Tourtelot, 1970). Sulfide-rich rocks of the Anakeesta Formation and some other meta-shales of the Central Appalachians contain trace to minor amounts of base-metal sulfide minerals, primarily pyrrhotite, with minor pyrite, and minor to trace chalcopyrite and Cu-sulfide minerals, and locally trace sphalerite and galena. In contrast, sulfide-bearing portions of the Penobscot Formation, a graphitic schist thought to have formed in a deep-sea, anoxic depositional environment (Stewart, 1998), contain trace to minor amounts of base-metal sulfide minerals primarily in the form of anisotropic pyrite, arsenian-pyrite, and pyrrhotite with accessory arsenopyrite, and trace to minor amounts of chalcopyrite, sphalerite, and galena, and other Pb, As, Ni, and Co-bearing sulfide minerals (Horesh, 2001; Foley and others, 2002). In the Northern Appalachians of Maine and New Hampshire, bedrock wells for domestic use have been shown to contain significant contaminants including high levels of arsenic (Ayotte and others, 1999). The differences in primary mineralogy for shales from the Central Appalachians compared to those from the north, have resulted in distinct geochemical and mineralogical characteristics for

weathering products. Distinct characteristics that may, in part, control the chemistry of surface and ground waters that traverse the rocks. Understanding the mineralogical and geochemical factors that contribute to natural acid rock drainage in the Eastern United States can be useful in predicting expected background compositions and levels that may be used to accurately assess the environmental impacts of man-induced acid drainage.

Table 1. Representative compositional ranges for selected elements of shales from locations within the Eastern United States, excluding mines [1. This study; 2. Stewart, 1998; Robinson and others, 2000, Ayuso and others, 2001; 3. Guidotti and Van Baalen, 1999; 4. Wedepohl, 1969-1978]

Location	SiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	V (ppm)	As (ppm)	Cu (ppm)
Anakeesta Formation[1]	40.9-78.0	9.7-28.0	1.4-10.3	60-160	<0.6-77	<2-105
Penobscott Formation[2]	38.2-74.4	1.8-16.9	1.3-10.4	77-1600	0.2-94	13-70
Smalls Falls Formation[2,3]	58.4-74.6	12.6-19.7	3.9-19.5	81-166	2.8-15.0	
Average shale[4]	63.82	16.92	7.11	10-200 (5000+)	<0.2-50 (100+)	5-110 (300+)

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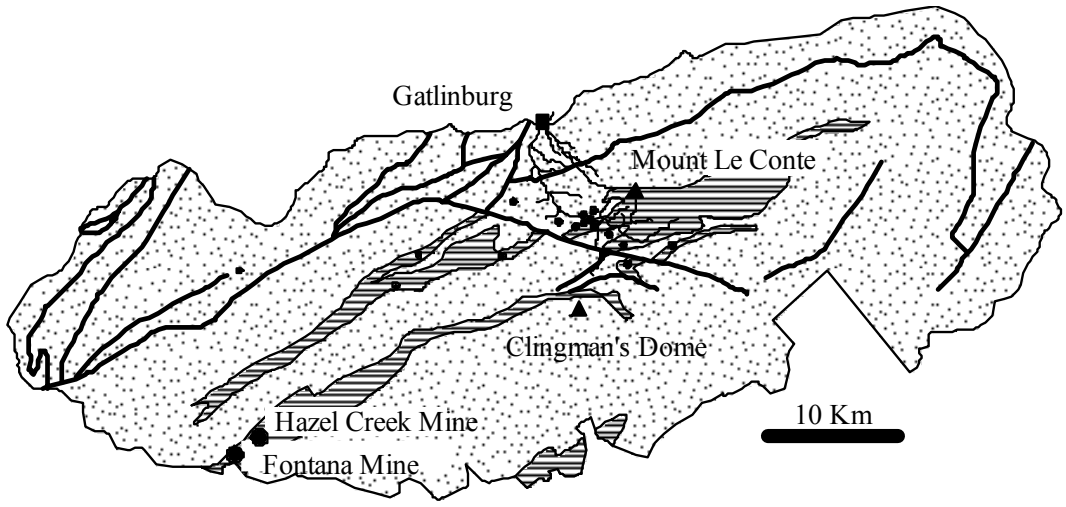

Figure 1. Generalized lithologic map of the Great Smoky Mountains National Park showing the distribution of various rock types and meta-shale sample locations. The location of the West Prong River in shown for reference. Heavy lines are fault boundaries. Modified from Southworth (1995).

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Indicator-Bacteria Concentrations in a River with Designated Uses of Drinking Water and Recreation, Metropolitan Atlanta, Georgia, 1999–2000—an Example from a Headwater Piedmont Watershed

Elizabeth A. Frick and M. Brian Gregory

DESCRIPTION OF PROPOSED PAPER

Metropolitan Atlanta is centered near the headwaters of the Chattahoochee River—which has a narrow, small watershed within the Blue Ridge and Piedmont physiographic provinces in northern Georgia. The Chattahoochee River is one of Georgia's most utilized water resources. The Chattahoochee River and Lake Sidney Lanier supply 72 percent of Metropolitan Atlanta's water supply and receive most of the region's treated wastewater as well as untreated urban runoff (Stevens, 2001). The population of the 10-county Metropolitan Atlanta area was more than 3.3 million people in 2000 (Atlanta Regional Commission, written communication, 2001). At the City of Atlanta's drinking-water intake, the Chattahoochee River watershed is 1,460 square miles, which is one of the smallest watersheds providing most of the water resource needs of any major metropolitan area in the US (Stevens, 2001). Microbial contamination is an issue in the Chattahoochee River watershed due to the high numbers of people using the Chattahoochee River as a drinking-water supply and recreational resource and the potential sources of contamination such as nonpoint runoff and treated and untreated wastewater effluent. Similar microbial contamination problems probably exist in other watersheds throughout the Appalachian region that have large population bases relative to the size of the watersheds and have designated uses of drinking water and recreation.

In 1999, the U.S. Geological Survey (USGS) in cooperation with the National Park Service, began a two-year study designed to evaluate microbial contamination in streams in and near the Chattahoochee River National Recreation Area (CRNRA). The CRNRA is comprised of 14 park units and the 48-mile reach of the Chattahoochee River downstream from Buford Dam which forms Lake Sidney Lanier to Peachtree Creek which drains most of downtown Atlanta.

The broad objectives of this study were to investigate the existence, severity, and extent of microbial contamination in the Chattahoochee River and eight major tributaries within the CRNRA. This was accomplished by (1) summarizing existing recent fecal-coliform data (Gregory and Frick, 2000) (2) conducting routine monitoring of three indicator-bacteria at three sites on the Chattahoochee River from March 1999 to April 2000 (3) conducting synoptic surveys at four mainstem and eight tributary sites during low-flow and storm-flow conditions and (4) conducting diurnal sampling at one mainstem site (Gregory and Frick, 2001). This proposed paper will summarize fecal-coliform bacteria, *E. coli*, and enterococci concentrations and potential variables affecting indicator-bacteria concentrations for the Chattahoochee River and its tributary streams from March 1999 to April 2000.

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A Low-Cost and Effective Method to Help Characterize Flow in Piedmont Fractured Crystalline Rock, Marietta, Georgia

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ABSTRACT

Ground-water flow through Piedmont fractured crystalline rock is being characterized, in part, through the use of passive-diffusion-bag (PDB) samplers in creeks in Marietta, Georgia. PDB samplers are inexpensive to maintain and reliable to use (Vroblesky and Hyde, 1997). The target volatile organic compounds are chlorinated ethenes, particularly trichloroethene, emanating from nearby Air Force Plant 6 (AFP6). During low-flow conditions, streams are mostly fed by ground water. Fractured crystalline rock is a dominant rock type in Appalachia. The concentration of TCE and its degradation products and their locations within water from creeks during low-flow conditions are used to infer the source of the contamination and how it flowed through the crystalline rock to the end of the ground-water flow path into the ground-water-fed stream.

PDB samplers are suspended in surface water in continuous-flowing (ground-water-fed) streams near AFP6. Many volatile organic compounds including chlorinated ethenes readily diffuse across the polyethylene plastic lining of PDB samplers. Chemistry of water from the PDB samplers equilibrates to the average chemistry of the ambient water within 2 weeks.

Samples collected in 2000 October from PDB samplers indicated discrete locations where dissolved TCE was entering Rottenwood Creek, a ground-water-fed stream, near AFP6 (Gonthier and Waddell, 2001). PDB samplers are currently being installed in Rottenwood Creek as well as other ground-water-fed streams in the area. Other data-collecting activities to characterize flow in fractured crystalline rock on and near AFP6 include well logging, well-packer sampling, and aquifer tests.

Understanding how dissolved TCE flows through the subsurface helps both understand ground-water flow through fractured crystalline rock and human-health risks associated with dissolved TCE contamination in fractured crystalline rock. The use of PDB samplers in Appalachia will provide a low-cost, effective method to assess the presence volatile organic compounds flowing through fractured crystalline rock and into ground-water-fed streams.

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Water Quality of Springs in Carbonate Rock in the Upper Tennessee River Basin, 1997

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In fall 1997 in the upper Tennessee River Basin, 35 springs in carbonate rock of the Valley and Ridge Physiographic Province were sampled for nutrients, bacteria, pesticides, and volatile organic compounds (VOC's) as part of the National Water-Quality Assessment Program (NAWQA). Of the 35 randomly selected springs 17 were utilized as untreated drinking-water supplies. Land use in the area surrounding the springs includes a mixture of urban, agricultural, and forested land use. Discharge from the springs ranged from 0.02 to 4.3 cubic feet per second, with a median value of 0.32 cubic foot per second.

Nitrate concentrations were low, generally less than 2 milligrams per liter (mg/L); however, fecal-indicator bacteria were detected in all 35 springs. Nitrate ranged from 0.091 to 2.17 mg/L, with a median concentration of 1.16 mg/L. Total coliform counts ranged from 10 to 1,900 colonies per 100 milliliters (col./100 mL) and *Escherichia coli* ranged from less than 1 to 660 col./100 mL. All water samples collected from the springs exceeded U.S. Environmental Protection Agency primary bacteriological drinking-water standards for public water supplies.

Pesticides and VOC's were detected frequently at low levels. Eight pesticides or degradation byproducts were detected in samples from 24 of the 35 springs. The most frequently detected pesticides were atrazine (57 percent of springs), deethylatrazine (atrazine-degradation byproduct, 54 percent), tebuthiuron (31 percent), prometon (17 percent), simazine (9 percent), and metolachlor (9 percent). Alachlor and p,p'-DDE each were detected once. Concentrations of the detected pesticides were less than the U.S. Environmental Protection Agency drinking-water maximum contaminant levels (MCL's), but some pesticides were detected more frequently in the springs than the national detection frequency of pesticides in ground-water samples from wells in other NAWQA studies. Of all the pesticides detected, the median concentration was 0.005 micrograms per Liter (μg/L), and the maximum concentration was 0.539 μg/L of tebuthiuron. Concentrations of VOC's detected in the springs were below applicable MCL's. As many as 9 VOC's were detected at a single spring; overall, 22 VOC's were detected in samples from 30 of the 35 springs. The majority of the VOC's detected were industrial-related compounds. The median VOC concentration was 0.03 μg/L, and the maximum concentration was 9.51 μg/L of methyl *tert*-butyl ether. The detection frequencies for VOC's in the springs were less than the national detection frequencies for wells in urban settings and greater than the national detection frequency for wells in rural settings.

Landscape Influences on Ambystomatid Salamander Populations in the Delaware Water Gap National Recreation Area

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The Leetown Science Center's Aquatic Ecology Lab is conducting a three year, multidisciplinary study on the distribution, population status, and genetic structure of ambystomatid salamanders and in the Delaware Water Gap National Recreation Area (DEWA). Our goal is to describe landscape characteristics that are important to the distribution of ambystomatid salamanders so that park officials can make informed decisions pertaining to the management of artificial impoundments, beavers, roads and trails, riparian zones, and areas leased for agriculture. We will survey approximately 90 bodies of water each season that will represent landscape strata that have been shown to be important to the distribution of amphibians (vegetative cover, topography, hydroperiod, and habitat patch isolation). In addition, we will collect salamander embryos from a sub-sample of these ponds to look at the genetic structure of populations of ambystomatid salamanders throughout the park. The dynamic nature of vernal pool communities offers fertile ground for collaboration with other DOI scientists. Potential areas for collaboration include the use of remote sensing techniques to predict the location of vernal ponds, studying trophic relationships between invertebrate and larval amphibian communities, and compiling a range-wide study of the genetic structure of ambystomatid salamanders in the Appalachian region.

Amphibian Research and Monitoring in the Appalachian Region

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The greatest biological diversity of amphibians north of Mexico occurs in the eastern United States, but amphibian populations in this area are subject to serious threats. Such threats include habitat degradation, fragmentation, and loss, as well as point and nonpoint source pollutants. In response to global concerns for amphibian health and survival, the USGS Amphibian Research and Monitoring Initiative (ARMI) was organized to monitor the status and trends of amphibians within the United States. Although ARMI is national in scope, two of its regions (Northeast and Southeast) encompass the Appalachian Region. Biologists and hydrologists are working together in the program to understand the biological and hydrological factors that affect amphibians and their habitats. The multidisciplinary effort links field research on amphibian life history and population status with water-quality and hydrological data collected at study sites. This poster describes ARMI research in progress in the Appalachian Region, primarily focusing on the Shenandoah and Great Smoky Mountains National Parks.

Ground-Water Exploration and Development in Igneous and Metamorphic Rocks: Part II—Case Histories from the Southeastern Piedmont/Blue Ridge Province

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Growing demand for water, combined with the current drought in the Piedmont and Blue Ridge Provinces of northern Georgia, has pushed many local and municipal water systems to, or beyond, their limits. Many of these water systems rely almost completely on surface water. Ground-water resources in the Georgia Piedmont/Blue Ridge may prove to be a significant supplemental source of water to large surface-water systems. Despite the fact that Piedmont/Blue Ridge ground-water resources have been largely ignored, numerous communities have successfully operated ground-water systems for many years.

There is a general misconception that there is little ground water in igneous and metamorphic rocks in the Piedmont/Blue Ridge. Because of this, ground water typically has been ignored or deemed unreliable as a resource. Compounding this misconception, many techniques used for locating ground water in these kinds of rock are unreliable. Non-scientific and scientific methods for selecting drilling sites have further hindered developing ground water as a supplemental water source.

Unlike Coastal Plain aquifers, which can supply large sustainable quantities of ground water, igneous and metamorphic rock aquifers in the Piedmont/Blue Ridge are less predictable. These rocks have little primary porosity or permeability, and locating ground water as a resource requires that zones of secondary porosity and permeability, such as joints, stress-relief fractures, and other water-bearing openings in the subsurface be located as precisely as possible. To accomplish this, a good understanding of the site-specific geology is of utmost importance.

Geologic approaches for evaluating ground-water potential in igneous and metamorphic rocks have improved chances of locating sustainable sources of ground water. These evaluations begin with detailed site-specific geologic mapping to identify: 1) rock type(s); 2) discontinuities, due to compositional differences (layering) and fractures (joints and/or faults); 3) topography; 4) type and depth of weathering; 5) nature and extent of the recharge area; 6) spatial relationships of rock types and discontinuities to topography, type and depth of weathering, and recharge area.

Case studies from Spalding, Carroll, and Gwinnett Counties, Georgia, are presented to show examples where communities have conducted ground-water exploration programs only to drill dry holes or low-yielding wells, even where the exploration programs used “high-tech” approaches that were thought to be the best tools for finding ground water. The flaw in many of these exploration programs is the lack of knowledge of site-specific geology. Without basic geologic data and an understanding of the detailed characteristics of the rocks in the targeted area, exploration programs have had little success.

Applying sound geologic methods for evaluating ground-water potential in igneous and metamorphic rocks have improved chances of locating sustainable sources of ground water in the Piedmont/Blue Ridge. When an appropriate scientific approach is taken, the probability of locating successful water wells is greatly increased.

Monitoring Coliform Bacteria in a Piedmont River Arising from the Appalachian Region of Northern Georgia

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Because of historically high levels of indicator bacteria in the Chattahoochee River, the concept of a bacteria alert network was proposed as a means to inform people when bacteria levels in the river exceed U.S. Environmental Protection Agency (USEPA) criteria. Thus, a program of bacteria monitoring called BacteriALERT was initiated on the Chattahoochee River within the Chattahoochee River National Recreation Area (CRNRA, National Park Service) in Fall 2000. The CRNRA contains about three-fourths of all public green space in a 10-county area of Metropolitan Atlanta, Georgia. In 1999, the recreation area attracted about 2.9 million visitors with nearly 30 percent of those participating in water-based recreation. Within the area of the bacteria alert network, drinking water and recreation are the designated uses for the Chattahoochee River.

BacteriALERT is a partnership between State and Federal agencies and non-government organizations. This partnership includes the Georgia Environmental Protection Division, the National Park Service, and the U.S. Geological Survey (USGS) and non-governmental organizations such as the Upper Chattahoochee RiverKeeper, Georgia Conservancy, Trust for Public Lands.

The main objective of this network is to collect and analyze water samples for total coliform and *Escherichia coli* (*E. coli*) bacteria at two sites on the Chattahoochee River upstream from Atlanta, Georgia, and post the results on a publicly accessible web site within 24 hours of data collection. A second objective is the statistical analysis and interpretation of these data under a wide range of seasonal, weather, and river conditions.

Water samples are collected four days per week (Monday-Thursday) using USGS-approved methods. The method uses a weighted-yoke to hold a sterile, narrow-mouth, 1-liter polypropylene bottle. A single, vertically integrated sample is collected at the center of flow. Turbidity and specific conductance in collected samples are measured in the laboratory. All analyses are completed in the bacteria laboratory at the USGS office in Atlanta, Georgia.

The bacteria analysis for total coliform and *Escherichia coli* is an enzyme substrate method called Colilert that is analogous to the commonly used multiple tube method. Bacteria counts are expressed as a most probable number (MPN) per 100 milliliters (mL). Three or four different dilutions are prepared for each site by adding an aliquot of sample to sterile, deionized/distilled (DI) water to produce 100 mL of liquid. A powdered reagent is added to each dilution bottle and the mixture added to a sterile, plastic tray containing 97 wells and incubated for 20 hours at 35 degrees Celsius. The wells produce a yellow color when total coliform bacteria are present and fluoresce under UV light when *E. coli* are present. Quality control is maintained by using sterile technique, collecting duplicate samples, and analyzing split samples using membrane filtration methods. Total coliform, *E. coli,* and fecal coliform bacteria are intermittently analyzed using the standard membrane filtration methods. Total coliform and *E. coli* filters are incubated in HACH's m-Coliblue24 broth.

In the twelve months of operation, a broad spectrum of people have visited the BacteriALERT web site for bacteria information before using the river. Many of those using the site are students, teachers, fishermen, kayakers/river rafters, and university rowing teams.

Statistical analysis has shown that (1) fecal coliform levels are strongly correlated with the total coliform and *E. coli* levels using the Colilert method; (2) only 15 to 35 percent of samples exceeded the U.S. EPA criteria; (3) *E. coli* levels exceeded the criteria when turbidity measurements were greater than 25 to 45 NTU; (4) *E. coli* levels are strongly related to river turbidity which are strongly related to increases in river discharge during and after rain storms; and (5) E. coli levels are higher during summer months than during winter and spring months.

In comparison, limited sampling in a stream that drains a natural, non-urban, undeveloped watershed within a state park shows that *E. coli* levels commonly exceeded the USEPA criteria, especially during the summer months. The highest E. coli count to date in this stream is 3,500 colonies /100 mL, more than 10 times the USEPA criteria of 235.

Terrestrial Carbon Sequestration – A Potential Land-Use Management for Mitigation of Greenhouse Gas Emissions

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If carbon sequestration is to be seriously considered as having a role in reduction of greenhouse gas (GHG) emissions, then it is imperative to know how terrestrial carbon is cycled and distributed on the landscape. Only then can we estimate the cost/benefit ratio of using terrestrial carbon sequestration to offset the effects of GHG emissions. In most terrains, the most stable long-term reservoir for terrestrial carbon sequestration is the soil. Analysis of soil organic carbon (SOC) storage data for the Appalachian region indicates distinct associations between spatial patterns in SOC distribution and regional variation in parent material (rock type), climate (elevation/aspect), and vegetation. Data analysis also suggests that SOC inventory estimates vary widely, depending on which datasets are used for storage calculations (aggregate versus site-specific), and on the scale of the map to which the data are linked. Understanding the factors controlling SOC storage and the reliability of the SOC inventory data is the first step in identifying those areas with the greatest potential to sequester SOC. These areas can then be given the highest priority for targeted efforts in land restoration/protection.

For the past several years the U.S. Geological Survey (USGS) has been investigating the role of SOC in the global carbon cycle. Data from these investigations now allow us to begin to (a) "map" SOC at national, regional, and local scales; (b) calculate present SOC storage at the land surface; (c) identify those areas with the greatest potential to sequester SOC; and (d) identify where these areas are coincident, and where they could be included, with lands targeted by local, State, and Federal agencies for watershed protection, "greenspace" development, or animal migration-route connection.

The initial task in achieving the first three objectives is to determine current levels of terrestrial SOC stocks and enable estimates to be made of net changes in SOC stocks related to landuse and climate change. The most readily available method to estimate SOC inventory for the surface meter of any land area in the United States is to use either of two U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) geographic databases (U.S. Department of Agriculture, 2001a,b)—the Soil Survey Geographic database (SSURGO, 1:24,000) or the State Soil Geographic (STATSGO, 1:250,000) database. These databases provide a powerful GIS framework for calculating SOC inventories at scales ranging from county (SSURGO) to national (STATSGO). Soil series comprising SSURGO map units are characterized by soil-attribute and related ancillary data in the USDA-NRCS Map Unit Interpretations Record (MUIR) database (U.S. Department of Agriculture, 2001c). STATSGO map units are characterized by a more generalized version of MUIR, the USDA-NRCS Soil Interpretations Record (SIR) database (only available as part of STATSGO). MUIR and SIR are aggregate databases that include variables such as organic matter, texture, slope, water content, and vegetative cover to describe map-unit components (soil series).

Although MUIR and SIR are similar, neither database captures the spatial variability in soil properties at the series level. Differences between SSURGO-scale and STATSGO-scale estimates of SOC inventory are primarily influenced by scale-related differences in map-unit composition. Soil-series characterization by MUIR/SIR data is not statistically consistent and therefore provides, at best, a semi-quantitative estimate of SOC inventory.

Compilation, synthesis, and linkage of site-specific soils data to SSURGO/STATSGO map units provides an empirical alternative to MUIR/SIR. Comparative estimates of SOC inventory for selected areas within the Appalachian Highlands physiographic division (Fenneman, 1938) were calculated using SSURGO map units linked to MUIR, STATSGO map units linked to SIR, and site-specific data linked to

both sets of map units. The site-specific soils data included approximately 10,000 soil pedon records from the USDA-NRCS National Soil Survey Center Soil Survey Laboratory Characterization Database (U.S. Department of Agriculture, 2001d); state databases for Arkansas (E.M. Rutledge, University of Arkansas, Fayetteville, Arkansas, unpub. data, 2001), Illinois (University of Illinois, 2001), Louisiana (Schumacher and others, 1988); and numerous small databases provided by individual researchers. Differences in the results were related to map scale, the percentage of each map unit represented by data, and how well contributing soil series were represented by data.

Initial comparative estimates of SOC storage demonstrate that STATSGO map units are the most appropriate for regional analysis, whether they are linked to their associated SIR data or to site-specific data, and that SSURGO map units linked to site-specific data provide the information needed for county-level analyses directed at identifying specific areas with high potential for SOC sequestration. It is these areas that are, or will be, of greatest interest to those parties charged with the regulation of landuse directed at increasing carbon sequestration.

SOC storage data for seven western North Carolina counties in the Blue Ridge and Piedmont physiographic provinces (table 1) indicate elevation as a major control on carbon storage in the ridge/sideslope and footslope soils. High-elevation ridge/sideslope and high-elevation footslope soils generally have higher SOC storage than low-to-medium-elevation soils in these landscape positions. This elevation gradient is possibly related to elevational changes in temperature, moisture, and vegetation. Slope angle also appears to be a control for footslope soils, with SOC storage increasing as the slope increases. There are no data available for high-elevation floodplain/terrace soils. SOC storage values for low-to-medium elevation floodplain/terrace soils are higher than those values for either ridge/sideslope or footslope soils at similar elevations. Thus one can postulate that higher elevation ridges and sideslopes, higher elevation footslopes in steep terrain, and lower elevation alluvial valleys are possible environments with greater SOC sequestration potential. Analysis of geographic patterns in SOC storage within the context of climate, geomorphology, and vegetation can provide a process-based approach to the identification of these areas within the landscape.

Ongoing efforts promise to show that merged SOC inventory and land-use databases can be used to identify areas with high SOC sequestration potential that are coincident with lands targeted by local, State, and Federal agencies for watershed and well-head protection, floodplain and wetland restoration and(or) protection, cropland reserve programs, mammal and bird migration route connection, and urban/suburban greenspace-corridor creation/restoration/connection. Identifying and studying the characteristics of landscape positions with high SOC sequestration potential may also result in additional land corridors being considered for, or designated as, set-aside areas for carbon sequestration. Some examples include land buffers along interstate highways, rail lines, and utility rights-of-way.

The actions required to successfully implement these programs require the cooperation of individual, corporate, municipal, state, and federal land owners. To obtain this degree of cooperation, there are two essential requirements: (a) that identification of priority areas be based on as much detailed geologic, geomorphic, biologic, and socio-economic data as can be obtained; and (b) that data syntheses be made available so that each land owner can assess the potential gains or losses of the recommended land-use changes. Ongoing efforts of the USGS to address these needs include:

- compilation and synthesis of site-specific data needed to estimate carbon storage and inventory in the soils, reservoir sediment, wetlands, and lakes of the conterminous United States;
- characterization of present-day carbon storage by landscape feature and environment; and
- prediction of potential carbon storage for land areas identified as possible reserves for carbon sequestration.

Table 1. Soil organic carbon (SOC) storage in the top twenty centimeters for six western North Carolina counties, based on the USDA Natural Resources Conservation Service Soil Survey Geographic (SSURGO) database map units

[Comparative SOC storage estimates are presented by landform and elevation for Ashe, Jackson, McDowell, Mitchell, Polk, Rutherford, and Yancey Counties in the Blue Ridge and Piedmont physiographic provinces of North Carolina. Elevation ranges -- low, 0-2000 feet; medium, 2000-4000 feet; high, 4000+ feet. Slope ranges -- low, 0-15 percent; medium, 15-40 percent; high, 40+ percent. SOC storage estimates for SSURGO map units in these counties are based on two data sources: 1 - site-specific soil pedon data linked to the map units by soil series (SSURGO map-unit components) and 2 - SSURGO layer-table data linked by soil series.]

			SOC storage based on site-specific pedon data		SOC storage based on SSURGO layer tables	
Landscape position	**Elevation range**	**Slope range**	**Number of SSURGO map units[1/]**	**Median, minimum, and maximum storage (kg/m^2)**	**Number of SSURGO map units**	**Median, minimum, and maximum storage (kg/m^2)**
ridge/sideslope	low	low-medium	1[31]	**3.3** 3.3-3.3	32	**1.4** 0.9-2.2
	medium	medium	63[11]	**3.8** 2.9-10.8	74	**3.4** 2.0-16.3
		high	108[3]	**4.8** 1.9-17.5	111	**4.8** 1.3-15.6
	high	medium	15	**9.7** 9.2-10.4	15	**15.2** 6.7-67.4
		high	25[6]	**9.2** 8.6-9.8	31	**14.0** 8.4-17.2
footslope	low	low-medium	0	--	11	**1.1** 1.1-2.0
	medium	low	9	**3.6** 2.7-4.2	9	**2.4** 2.2-7.4
		medium	49[1]	**6.0** 1.6-10.5	50	**6.7** 0.4-16.6
		high	2	**6.8** 6.8-6.8	2	**10.9** 10.9-10.9
	high	medium	7	**11.6** 11.5-12.3	7	**11.9** 11.8-13.0
		high	3	**13.1** 13.1-13.1	3	**6.8** 6.8-8.3
floodplain/terrace	low-medium	low-medium	19[39]	**6.5** 1.9-11.5	58	**5.1** 1.1-55.6

[1/]Numbers in square brackets are the number of SSURGO map units for which there are no data available for any of the soil series in the map unit.

Some examples of active projects include:

New Jersey Department of Environmental Protection *Well Head Protection Plan*, Division of Science and Research, Geological Survey, <http://www.state.nj.us/dep/dsr/wellhead.pdf>

Tennessee Department of Environment and Conservation, Division of water Supply, *Wellhead Protection Program*, <http://www.state.tn.us/environment/dws/wellhdbro.html>

U.S. Environmental Protection Agency (EPA), *Upper Basin Project*, floodplain restoration and sustainability, St. Johns River Water Management District, <http://yosemite.epa.gov/water/restorat.nsf/>

EPA *Southeastern Ecological Framework Project*, GIS-based analysis to identify ecologically significant areas and connectivity, <http://www.geoplan.ufl.edu/epa/>

US Department of Agriculture, *Crop Reserve Enhancement Program (CREP)*, for example, in Missouri, 50,000 acres of highly erodible and environmentally sensitive cropland along streams that supply 83 reservoirs are being retired to CREP (USDA Office of Communications, News Release No. 0316.00) <http://www.fsa.usda.gov/pas/news/releases/2000/09/0316.htm>

Cook County, Illinois *Forest Preserve District*, <http://www.co.cook.il.us/secretary/HomePage_Links/whats_cookin_in_cook_county_book.htm#COOK COUNTY FOREST PRESERVE DISTRICT>

City of Chicago's *The Chicago Brownfields Initiative* <*http://www.ci.chi.il.us/Environment/Brownfields/Index.htm*>

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University of Illinois, 2001, Soil Characterization Laboratory Database, accessed February 15, 2001, at http://www.il.usda.nrcs.gov/soils/soil-lab.htm

Comparison of Bacterial Source-Tracking Methods and Investigation of the Sources of Fecal Contamination to Ground Water in Berkeley County, West Virginia

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Escherichia coli, indicators of fecal contamination, were detected in 16 of 50 domestic water wells that were sampled during the summer of 2000 in Berkeley County, West Virginia. This region is partially underlain by karstic limestone where ground water flows quickly and commonly interacts with surface water, which makes it difficult to link fecal contamination in ground water to aboveground sources. Bacterial source tracking will be a valuable tool to aid the State and County in their efforts to identify and control fecal contamination in ground water and will provide a tool for other bacterial contamination studies. Because the field of bacterial source tracking is in its infancy, no consensus is available regarding the best methods to address fecal contamination sources in environmental settings. This investigation will compare seven bacterial source-tracking methods for their ability to discriminate *Escherichia coli* isolates from feces of different source-animal categories in Berkeley County. Method performance will be assessed by challenging a library of known-source isolates with a blind library of isolates. The animal sources of the blind-library isolates will be known to the project chief but not to any of the analyzing laboratories. Method performance will be assessed by the average rate of correct classification for isolates from each source group, the rate of false-identification within each source group, materials cost, and time cost. The best method in the comparison will be used in a field study to associate ground-water-contaminating *Escherichia coli* with their sources.

Forest Change Within Shenandoah National Park

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Due to fire, insect pests, weather events, human activity, and disease, the forests of Shenandoah National Park have undergone a variety of changes. This poster highlights geospatial technologies being used to analyze the past to better understand the present and future. Remote sensing is a powerful tool for revealing land cover change. A time series of Landsat Thematic Mapper imagery is being used to track the health of eastern hemlock (*Tsuga canadensis*) stands. These trees are being defoliated by the hemlock woolly adelgid (*Adelges tsugae*), an exotic aphid-like insect. By using a vegetation index, calculated from multispectral imagery (such as TM), it is possible to observe hemlock health over time and locate areas of change. With this information, it may be possible to predict which stands are most vulnerable to future infestations. Similar change detection techniques can be used to map one-time events such as the 1995 flood of the Staunton River. This 500+ year flood scoured several riparian areas causing significant change to stream drainages.

Historical data is instrumental in mapping current vegetation communities. Geographic representations of fire history, gypsy moth defoliation, hurricane and ice damage, along with analyses described above aid researchers in understanding forest flora and structure. Past maps of vegetation, including an exceptional digitized version of a 1941 report, reveal important information about forest age and species occurrence. All of this information about forest history will be combined with current remotely sensed data and ecological modeling (see poster by Young et al.) to get a detailed map of present vegetation community distribution.

Effect of Clearcutting on Nitrogen Export from a Watershed in the Catskill Mountains, New York

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The Catskill Mountains of New York receive high rates of nitrate deposition (10-12 kg/Ha/yr). and many streams have measurable nitrate concentrations throughout the growing season. Approximately 16 hectares of a 22-hectare watershed in the Catskills was clearcut during the winter of 1996-97. Soil- and surface-water quality was monitored for 4 years prior to the cut, and monitoring has continued since. Nitrate concentrations in stream samples peaked at 1,400 μmoles/liter during the first summer following cutting. Patterns of stream nitrate concentrations in the 4 years following the cut are strongly similar to concentrations observed in the 4-year postcut period at Watershed 5 in the Hubbard Brook Experimental Forest. Nitrate concentrations in the Catskill clearcut appear to be rising to pre-cut levels during year 5 of the postcut period, while the 5th-year concentrations at Watershed 5 were at or near detection. Nitrification rates in Catskill watersheds are high relative to those reported from other areas of the Northeast (5-7 g N/m^2/yr), and showed little change as a result of the cut. The comparison of the two logging studies in watersheds receiving differing rates of N deposition suggests both short-term similarities and long-term differences in rates of nitrogen export following clearcutting.

Paleozoic through Cenozoic Uplift, Erosion, Stream Capture, and Deposition History in the Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain Provinces of Tennessee, North Carolina, Virginia, Maryland, and District of Columbia

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Fission-track (FT) analysis of zircon and apatite is helping define the Paleozoic through Cenozoic history of the Valley and Ridge (VR), Blue Ridge (BR), Piedmont (P), and Coastal Plain (CP) provinces of the Eastern United States. The oldest zircon FT ages from the VR and western BR are significantly older than those of the eastern BR and P provinces. This is apparent in the ranges of both sample ages and single-grain ages.

		FT age range (Ma)		
	Stratigraphic	Weighted mean sample ages		Single-grain ages
Province	age	Apatite	Zircon	Zircon
VR	Paleozoic	~200	~560	~380-~1160
western BR	Proterozoic-Paleozoic	~100-~155	~315-~920	~235-~1790
eastern BR	Proterozoic-Paleozoic	~95-~185	~265-~380	~200-~730
P	Proterozoic-Mesozoic	~130-~200	~260-~300	~200-~360
CP	Miocene	no apatite	~390	~45-~1340
CP	Cretaceous-Oligocene	~130-~155	~175-~280	~45-~795

Some VR and western BR rocks were never buried deeply enough during the Phanerozoic to obtain temperatures sufficiently high (>~225°C) to totally reset their zircon FT ages. In contrast, most zircon ages from the eastern BR and P show significant cooling from >225°C at ~300-280 Ma, most likely related to emplacement of major Alleghanian thrust sheets. Apatite FT data suggest that BR and P rocks underwent relatively slow, continuous cooling during the Mesozoic and Cenozoic, passing through the apatite FT closure temperature (~90-100°C) at a rate of about 16 m/m.y.

FT ages of detrital zircon in shallowly buried (<411 m) rocks in the CP reflect FT ages in the source terrain. The data suggest that the P and eastern BR were the major source of detritus from Cretaceous through Oligocene time. Old zircons comparable in age to those in the western BR and VR do not appear in CP rocks until early or middle Miocene. Preliminary interpretation is that major drainage from the western BR and VR was to the west prior to the Miocene--major east-flowing Mid-Atlantic rivers did not breach the Blue Ridge until early or middle Miocene time.

Concentration-Discharge Patterns in Acid-Neutralizing Capacity During Stormflow in Three Small, Forested Catchments in Shenandoah National Park, Virginia

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To provide insight into runoff processes, we examined variability of concentration-discharge (c-Q) plots of acid-neutralizing capacity (ANC) using a multiyear, multistorm hydrological and hydrochemical data set for three forested catchments in Shenandoah National Park, Virginia. The shape and rotational direction of c-Q plots (clockwise or anticlockwise) have been explained in the context of conservative mixing of three end members—surface-event, soil, and ground water. The streams draining the catchments represent a gradient in baseflow ANC, which is controlled by the underlying geology. We observed a trend in the fraction of anticlockwise rotation patterns, from the highest in the most acidic catchment to the lowest in the least acidic catchment. On the basis of previous modeling of c-Q plots, the trend across the catchments can be explained by differences in the concentration of the three end members, whereby the greater the differences (i.e., in the least acidic catchment), the fewer anticlockwise rotation patterns were observed. Differences in the relative volume and timing of the end members contributing to stormflow, ultimately controlled by the underlying geology, also may have contributed to the trend. Discriminant function analysis indicates that pre-storm baseflow ANC is an important predictor of rotation direction in two of the catchments; however, the predictive strength of the model decreases from the most acidic to the least acidic catchment. Variation of rotation patterns within a given catchment and across similar catchments can provide insight into factors and processes that influence runoff generation and solute transport.

GEODE – An Interactive Data Retrieval, Display, and Analysis Internet Application

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GEODE (Geo-Data Explorer) "http://geode.usgs.gov" is an Internet-based, USGS data delivery system that provides digital information to the desktops of clients and users by means of an innovative geographic information system (GIS) technology. GEODE uses a custom GIS interface developed by the USGS that allows policy-makers, land and resource managers, educators, private industry, and others to search for maps and databases, create custom map and data downloads, control map appearances, and display multiple layers of data for analysis. GEODE consolidates data from a variety of sources in order to simplify the data mining and decision-making process. GEODE was originally designed to disseminate energy related information including coal, oil, and gas datasets. However GEODE has developed to include additional datasets from the entire USGS Geologic Discipline, and it now provides selected data on volcanoes, earthquakes, geologic maps, climate change, ecosystems, minerals, coastal, and marine issues. These data sets may be combined with additional data layers and imagery such as satellite images, digital elevation models, transportation systems, census tracts, and population data. GEODE is a fast, accessible, spatial research and analysis tool that allows the user to perform resource estimates and risk assessment without the need for special hardware, software, or training.

Landscape Influences on Aquatic Assemblages: Fish, Bugs, and Salamanders

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As with birds, mammals and other terrestrial assemblages, the distribution and abundance of aquatic species are fundamentally linked to the landscape. Scientists at the Leetown Science Center's Aquatic Ecology Laboratory (AEL) conduct research aimed at better understanding the linkages between terrestrial and aquatic components of Appalachian ecosystems. This poster describes examples of basic and applied research conducted at AEL that evaluate landscape influences on aquatic assemblages. Showcased studies include research designed to: 1) determine the effects of urban and agricultural land use on stream fish assemblages in Ridge and Valley watersheds (VA, WV), 2) predict the impact of forest pests on aquatic biodiversity in the Delaware Water Gap National Recreation Area (PA, NJ), 3) assess aquatic invertebrate recovery patterns to a major flood in Shenandoah National Park (VA), and 4) develop empirical models that relate amphibian breeding pond selection to landscape and pond habitat factors in the Canaan Valley National Wildlife Refuge (WV). The poster is meant to depict the scope of landscape studies conducted at the lab and focuses on objectives, major findings, and opportunities for cross-discipline collaboration. Taken together, results of these studies highlight the need to integrate landscape-level information in order to manage aquatic ecosystems in the Appalachian region.

Hydrologic Hazards and Streamgaging Needs in the Appalachian Mountain Region

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Hydrologic hazards from floods, droughts, and landslides are major issues of concern in the Appalachian Mountain region. Often, hydrologic hazards result in loss of human life, property damage, disruption of lives, and various economic losses. The major issues are minimizing the potential adverse effects from hydrologic hazards; protecting and enhancing water resources for human health, aquatic health, and environmental quality; and contributing to wise physical and economic development of the Appalachian Mountain region resources for the benefit of present and future generations. To accomplish this, a better understanding of these hydrologic hazards and the design and implementation of better hydrologic-warning systems are needed.

Other hydrologic-hazard related issues are modifications or revisions to flood-frequency estimates for this region; developing the capability to rapidly identify changes in floodplain areas as a result of changes in land use; and conducting studies of long-term climate records to include the effects of climatic variability into water-resource planning.

An important first step to minimize the consequences of these hydrologic hazards is to analyze the current streamgaging program in the Appalachian Mountain region, add additional streamflow gages, and increase the percentage of stream gages that are equipped to deliver real-time data during floods and other adverse hydrologic conditions. Real-time data collection will include stream stage, stream discharge, precipitation, and selected water-quality characteristics.

Current USGS activities in the Appalachian Mountain region include—collecting, storing, and disseminating basic hydrologic data on the quantity and quality of water, and providing knowledge and expertise to assist various levels of government (Federal, State, and local) in understanding and solving critical local and regional water-resources problems.

The USGS currently operates continuous-recording data collection gages at about 350 streamflow gaging stations, 10 ground-water observation wells, 15 water quality sampling and monitoring sites, and 15 lake and reservoir locations in Alabama, Georgia, North Carolina, South Carolina, Virginia, and West Virginia within the Appalachian Mountain region. Of these about 390 total gaging locations, about 90 percent or 350 locations are real-time data collection and processing sites. USGS historical hydrologic data collection goes back as far as the late 1800's for many of the streamflow gaging stations.

Additional hydrologic data collection of streamflow, water quality, and ground-water resources are needed to adequately monitor and document important information that are becoming vital for critical water resources in the Appalachian Mountain area. These new collection activities will allow the USGS to work with partners from other Federal, State, or local agencies.

Research on Freshwater Mussels (Bivalvia: Unionidae) in Appalachian Streams

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North America has the richest freshwater mussel fauna in the world, with the greatest diversity concentrated in the eastern United States. However, this diverse fauna are among the most threatened animals in North America with over 70% considered to be endangered, threatened, or of special concern. Though the causes are varied the decline of freshwater mussels can be attributed primarily to degradation and loss of essential habitat. The unique life history of unionids may even contribute to their decline because of their dependence on an obligate fish host for successful reproduction. The introduction of nonindigenous bivalves, specifically *Corbicula fluminea* and more recently *Dreissena polymorpha*, may further the decline leading to local extinctions of native species. The precipitous decline in the molluscan fauna is projected to continue with at least 127 species expected to disappear within the next century. This rate of extinction rivals the estimated loss for tropical rainforest communities. Consequently, the study of freshwater mussel populations is of growing importance for conservation efforts to identify and sustain existing biodiversity. Estimates of population parameters, including life history traits and population density, play a role in research, conservation, and management of freshwater mussels. In 1994 the Leetown Science Center began a freshwater mussel research program focusing on conservation and restoration of native unionids. Studies have begun to address life history and ecology, conservation genetics and systematics, development of rigorous sampling methods for accurate assessment of species distribution and abundance, status and trends surveys, the effects of exotics on mussel ecology, and evaluation of relocation as a management tool through field experimentation. A new research effort will implement rigorous sampling methods to estimate the proportion of a large river system that supports reproducing populations and the frequency distribution of density of endangered species. Results of the river-wide survey will be combined with population modeling to assess site-specific impacts and predict consequences to the viability of the Allegheny River populations. Future research needs must also address conservation efforts at larger spatial scales. Efforts to correlate freshwater mussel distribution and density with site- specific variables have met with little success. Since native mussels spend most of their life burrowed within the river substrate, other environmental factors (e.g., interstitial dissolved oxygen, subsurface water flow) may be influencing mussel population distribution and abundance. The groundwater-surface water ecotone is an active component of stream ecosystems that influences whole-system processes that may play an essential role in structuring mussel populations. Collaborative studies are needed to evaluate whether groundwater influxes influence mussel distribution and population abundances, and to determine whether the relations among landscape features may be important in structuring mussel communities at the basin-wide scale.

Sample Design for Estimating Distribution and Abundance of Freshwater Mussels (Bivalvia: Unionidae) Within a Watershed

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Freshwater mussels are among the most threatened animals in North America. Though the causes are varied the decline of freshwater mussels can be attributed primarily to degradation and loss of essential habitat. The introduction of nonindigenous bivalves, specifically *Corbicula fluminea* and more recently *Dreissena polymorpha*, may further the decline leading to local extinctions of native species. Consequently, the study of freshwater mussel populations is of growing importance for conservation efforts to identify and sustain existing biodiversity. Estimates of population parameters, including population density, play a role in research, conservation, and management of freshwater mussels. However, if the freshwater mussel population in a river is unknown, the question becomes which sampling design is appropriate for describing mussel species and their abundance. Due to the patchy distribution of freshwater mussels at multiple scales, surveys should be designed to sample sites throughout the drainage or watershed to assure accurate assessment of species distribution and abundance. If just a few sites or only sites in relatively close proximity to one another are sampled, the risk is great that densities or richness will be severely under or over estimated. We devised, tested, and implemented a two-phase sampling design to determine the distribution and abundance of freshwater mussel populations in the Cacapon River in West Virginia. The two-phase design provided a framework for combining data from qualitative and quantitative sampling methods. Six species were identified, three of which are rare in the state, including *Lasmigona subviridis* and *Strophitus undulatus*, which were not reported previously from the Cacapon River. River-wide density of freshwater mussels in riffle habitats was estimated to be $0.61/m^2$ with variance = 0.0265. We found important differences in longitudinal distribution and abundance among species. *Elliptio complanata* was present throughout the river but was more abundant, had wider size distributions, and exhibited more recent reproduction within the upper reaches of the river. *Elliptio fisheriana*, second in abundance to *Elliptio complanata*, was abundant only within the lower to middle reaches of the river. Differences in longitudinal distributions have implications to mussel monitoring and conservation. Effective conservation may require protection of contiguous areas within a watershed to account for difference in species distribution and for the importance of dispersal among reaches. Otherwise, protection of only the densest reaches may fail to conserve all at-risk species.

Abundance and Movements of American Eels near Millville Dam, Shenandoah River, West Virginia

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The apparent decline of the American eel population has prompted recent management and conservation concerns. The Atlantic States Marine Fisheries Commission recently listed information and research needs, including needs for knowledge of abundance levels, movements, passage, age and sex of American eels. We are currently conducting a study of American eels in the lower Shenandoah River, West Virginia. The primary study objectives are (1) to quantify seasonal movements of eels by radio telemetry, mark-recapture techniques, and monitoring of fishways on the Millville Dam, and (2) to estimate seasonal abundance of eels near the vicinity of Millville Dam. Secondary objectives are to estimate age, sex, and level of parasitism (swim bladder nematodes) of eels in the lower Shenandoah River drainage.

The Role of Two-Dimensional Direct-Current Resistivity (2D DC-Resistivity) Profiling in a Water-Resource Investigation: Application to Ground Water Exploration and Development in Igneous and Metamorphic Rocks of the Georgia Piedmont/Blue Ridge

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Two-dimensional direct-current resistivity (2D DC-resistivity) profiling can be used in water-resource investigations to help to detect water-bearing zones in bedrock. In a cooperative project between the U.S. Geological Survey and the City of Lawrenceville, Gwinnett County, Georgia, resistivity profiling was conducted to help explore for transmissive water-bearing zones in igneous and metamorphic rock aquifers before test drilling. Results from surveys were used to site and drill several test wells. At one test site, resistivity profiling revealed water-bearing zones to a depth of 80 feet that were encountered in the test drilling.

A primary consideration in using resistivity profiling in water-resource investigations is the depth to which a resistivity profile can be reliably produced. In Lawrenceville, most of the high-yielding wells produced from transmissive zones at depths between 200 and 300 feet—well below the general practical depths that can be explored with resistivity profiling in this area. Resistivity imaging was generally conducted to a maximum depth of 180 feet using a dipole-dipole array of 83 electrodes spaced 13 feet apart (total array 1,089 feet long). An electrode spacing of more than 13 feet allows for a greater depth of penetration but with less resolution. The depth limitation of this technique and the resolution needed for discrete fracture zones often observed in Lawrenceville prevented the use of resistivity profiling for water-resource evaluations in the most productive water-bearing zones.

An equally important consideration in applying resistivity profiling in igneous and metamorphic rocks is correlating the electrical image to geologic features at the test site such as thickness of saprolite and resistivities of different rock types. Site-specific geologic maps were constructed for each area and structural measurements were taken. To improve interpretation of the resistivity data in Lawrenceville, profiling was conducted at a high-yielding well site and low-yielding well site. This provided valuable information on the effects of different arrays and electrode spacings required to provide adequate resolution of water-bearing fracture zones. Borehole electrical resistivity logs also provided direct measurements of rock resistivities in fractured- and unfractured-rock. This information is needed to develop reasonable interpretations of the resistivity data collected.

In Lawrenceville, fracture zones in the igneous and metamorphic rock aquifers are normally associated with a zone of low apparent resistivity. In almost every case, resistivity profiling allowed the imaging of shallow water-bearing zones but did not distinguish individual fractures in the bedrock.

If electrical resistivity profiling is used in water-resource investigations in igneous and metamorphic rock aquifers, every effort must be taken to correlate these data to geologic features at the site. Depth limitations and resolution of the target zone should be major considerations when applying this technique. If the target zone is deeper than what can be imaged by the system then this technique may not benefit the exploration effort. Electrical imaging techniques should also be used in conjunction with a good understanding of the site-specific geology so these data can be interpreted correctly.

Assessing Vegetation Community Composition in Relation to Environmental Gradients in Shenandoah National Park, Virginia

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A number of researchers have examined vegetation distribution in relation to environmental gradients derived from digital elevation data. Important gradients that recur in these studies are, slope direction, slope position, slope shape, moisture, light, and (less commonly) rock type, and elevation. We developed GIS-based environmental gradient models in an effort to accurately describe and map vegetation community composition in Shenandoah National Park, Virginia. The gradient models produced for this study were used to stratify the park into "ecological land units" and were used to locate representative field vegetation sampling plots. The gradient models produced will also help to guide remote sensing investigations, and will form the basis of GIS-based predictive modeling of vegetation distribution in future efforts. Aside from providing a map for National Park Service managers, this project will examine vegetation distribution patterns resulting from response to environmental gradients in contrast to human- and natural disturbance induced distribution patterns. This poster will discuss the derivation of environmental gradient models for Shenandoah National Park and the goals and progress to date on this research.

ADDITIONAL ABSTRACTS

Earthquake Hazard in the Appalachian Region
Joan Gomberg and Eugene Schweig

An Integrated Geographic Database and Web Site
Anthony V. Herr

Virginia Tech Cooperative Park Studies Unit
Jeffrey L. Marion

Restoration of a Native Brook Trout Fishery to the Upper Shavers Fork, a Large, High-Elevation Watershed in West Virginia
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Water Quality in the Coal Mining Areas of the Appalachian Plateau
Steve McAuley

Mesohabitat Use of Threatened Hemlock Forests by Breeding Birds of the Delaware Water Gap National Recreation Area
Robert M. Ross

Landscape Determinants of Nonindigenous Fish Invasions
Robert M. Ross, William A. Lellis, Randy M. Bennett, and Connie S. Johnson

On-Going Wildlife Research in the Southern Appalachians
Ted Simons

Influence of Water Quality, Stream Gradient, and Flooding on Fish Distributions in the New River Gorge National River
Stuart A. Welsh and David I. Wellman

Earthquake Hazard in the Appalachian Region

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The Appalachians host the Southern Appalachian seismic zone (SASZ), extending from Alabama to Virginia. The most active portion of the SASZ during the past 15 years, and perhaps longer, extends ~300 km from northwestern Georgia through east Tennessee, and is referred to as the East Tennessee seismic zone (ETSZ). The ETSZ is the second most active seismic region in the eastern U.S. (*Powell, et al*., 1994) (Fig. 1). On average, a few earthquakes of magnitude ~3.0 occur in the SASZ annually (the number of smaller magnitude earthquakes increases approximately tenfold for each magnitude unit decrease). The most seismically active region in the eastern US is the New Madrid seismic zone (NMSZ).

Most of the seismicity in the SASZ is attributed to reactivation of Precambrian age faults in the crystalline basement rocks buried beneath younger sedimentary rocks. The tectonic stress regime is thought to be essentially the same for the SASZ and NMSZ; the maximum stress is oriented nearly horizontal and trends east-northeast to west-southwest.

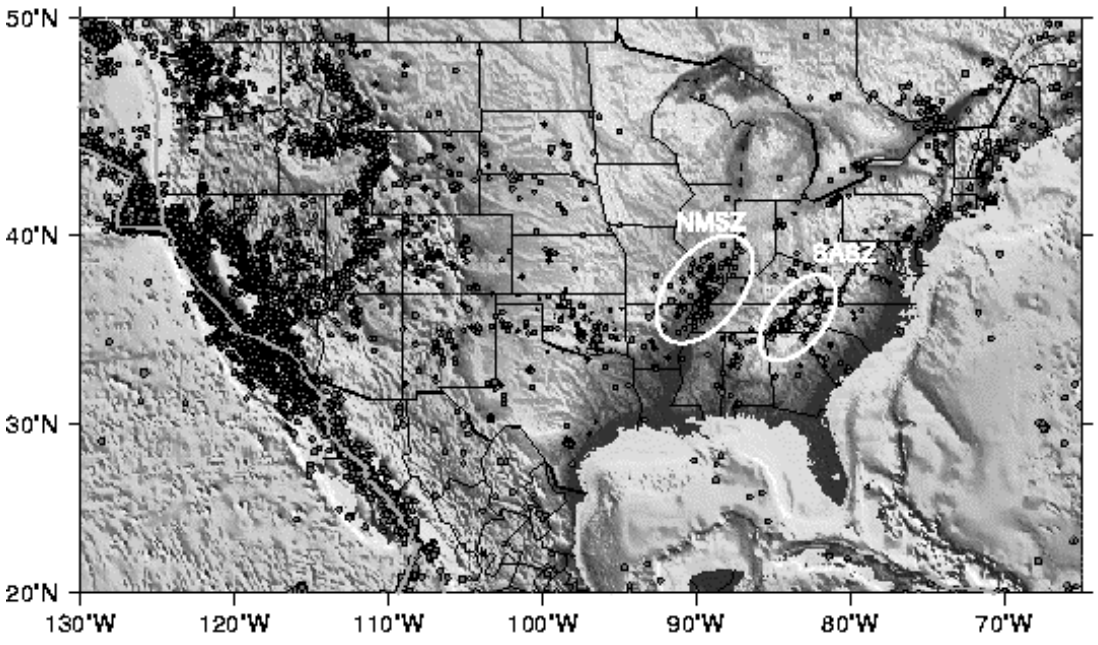

Figure 1. Earthquakes in the United States from 1977 to 1997 (from the USGS Natl. Earthquake Information Center). White ovals show approximate areas comprising the Southern Appalachian seismic zone (SASZ) and New Madrid seismic zone (NMSZ).

Assessing seismic hazard in the SASZ is made difficult by the fact that the zone has not experienced any earthquakes with magnitudes of 6.0 or greater in historic times. This does not mean that the region is not capable of producing a larger event, but simply that our observation time is much shorter than the time-scales over which large earthquakes occur. The largest known earthquake in the SASZ was the Giles County, Virginia earthquake of 1897, which had an estimated magnitude of 5.8. The largest known earthquake in the ETSZ was the magnitude 4.6, 1973 Maryville, Tennessee earthquake. Earthquake faulting in the ETSZ, at least as inferred from small, instrumentally recorded earthquakes, appears to occur between 5-26 km depth on steeply dipping strike-slip faults (*Vlahovic and Powell*, 2001).

Most of the SASZ region is covered by consolidated Paleozoic sedimentary rocks or crystalline rocks of Precambrian age. The scarcity of easily deformable rocks and sediments in the SASZ, rugged topography, and dense vegetation make seismic hazard assessment challenging, particularly the identification of prehistoric earthquakes from paleoseismic studies. To date, only a few such studies have been conducted and these produced no conclusive evidence of damaging prehistoric earthquakes. Unlike the NMSZ, however, liquefaction is not a significant earthquake-related hazard.

Earthquake monitoring has been the USGS's primary activity related to earthquake hazards in the Appalachians. The External Program of the USGS Earthquake Hazards Program has funded cooperative agreements to universities for the operations of several permanent monitoring networks in the SASZ. For the past two years much of the monitoring in the SASZ has been combined with network operations in the NMSZ, and all data acquisition and most processing efforts have been linked (Fig. 2) as part of the development of the US's Advanced National Seismic System (ANSS).

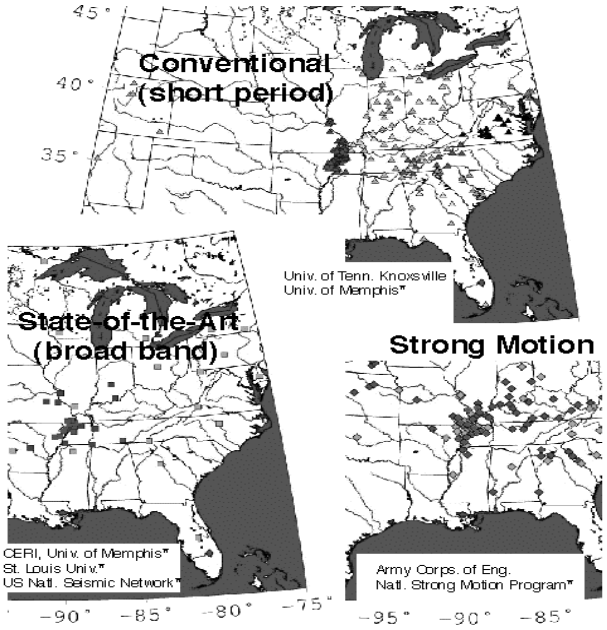

Figure 2. Symbols show locations of seismic monitoring stations of various types. Conventional stations (top) only record earthquakes on-scale in a very limited size range and in a limited spectral frequency band. More sophisticated broad band instruments (bottom left) record over a larger magnitude and frequency range. Strong motion stations (bottom right) are designed to record only the very large motions very close to the earthquake source and generally do not detect small earthquakes. The institutions responsible for monitoring are listed with asterisks denoting those supported by the USGS.

The Tennessee Valley Authority also monitors earthquakes in the SASZ and participates in data exchange in the region. The SASZ is part of the Mid-America region of the ANSS. One benefit of the ANSS has been unified reporting of earthquakes in near real-time and standardized dissemination of this information to the public (Fig. 3).

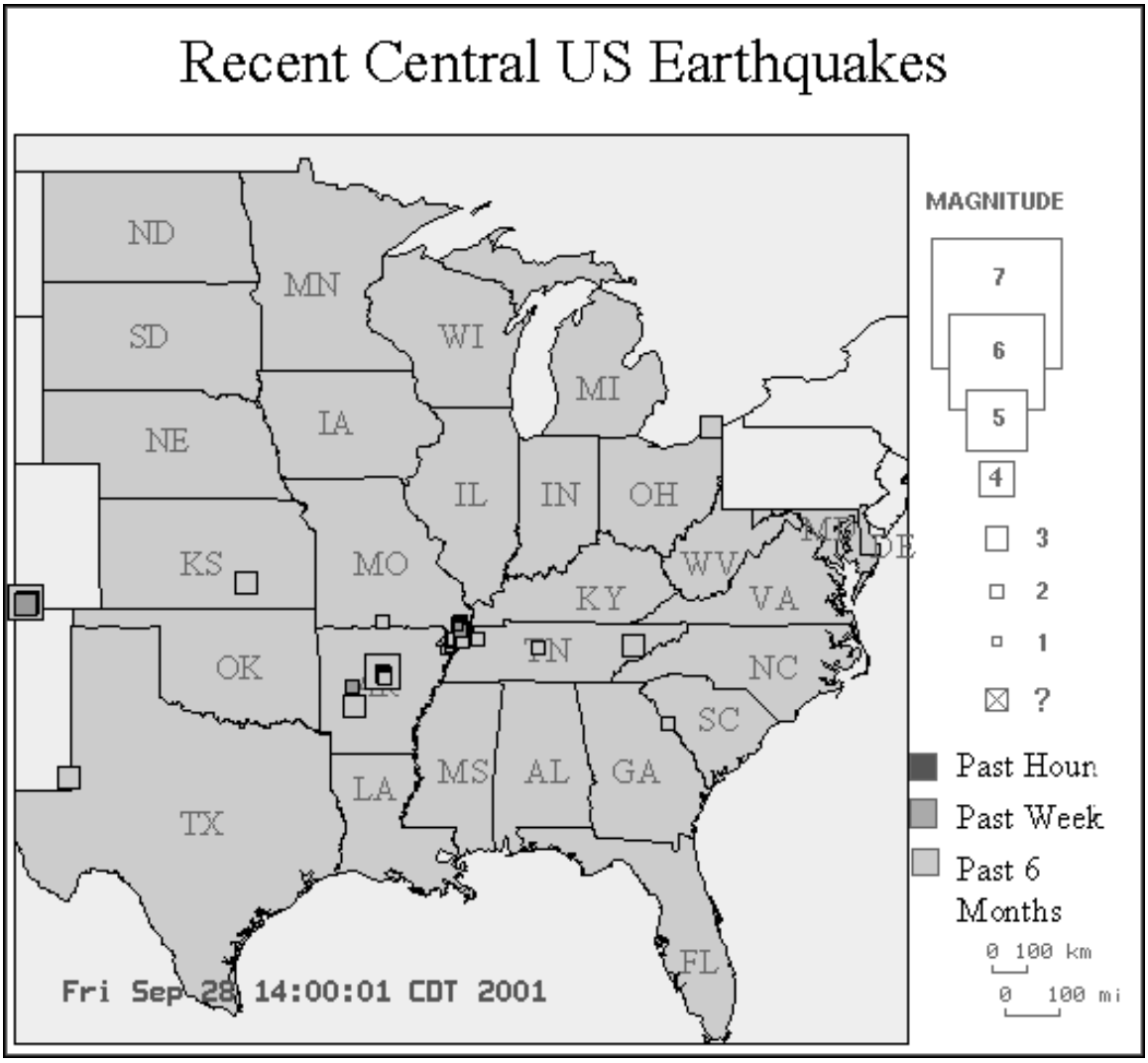

Figure 3. Example of how earthquake occurrence is reported in near real-time over the Web for the entire central and southeastern US. Similar pages are produced for other regions of the country, all using software developed by the USGS. The Web address is http://folkworm.ceri.memphis.edu/recenteqs/.

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An Integrated Geographic Database and Web Site

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An integrated database of information, including project data and reports, is an important component of an integrated science program. To make these data easily available and useable is part of the mission of the USGS. A Web-accessible database is a necessary step to ensure ease of use for scientists and the general public. Datasets would have formats common to many geographic information systems (GIS) mapping packages and analytical software packages. The proposed database would include base geographic, hydrologic and biologic information and other datasets, such as land cover, hazards information and population dynamics. These data would be organized by focus area to facilitate communications and research investigations. Data would be available either by direct download or through FTP from a dedicated Web site, which would be modeled after the South Florida Information Access site (SOFIA, http://sofia.usgs.gov) and would incorporate many of the ideas from the Southern Appalachian Information Node (SAIN). The goals of this activity complement many of the outreach and technical goals of the SAIN. Eastern Region Geography will develop this Web site and the database over the next 2 years if appropriate funding can be obtained.

Virginia Tech Cooperative Park Studies Unit

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The Virginia Tech Cooperative Park Studies Unit is a field station of the Patuxent Wildlife Research Center and is affiliated with the Department of Forestry Recreation Resource Management Program, College of Natural Resources. The focus of this unit is on the field of recreation ecology, defined as research and monitoring to identify, document and understand visitor-related impacts to protected area resources. An enhanced understanding of recreational impacts and their relationships with use-related, environmental, and managerial factors can aid managers in defining acceptable limits of change and in decision making necessary to balancing recreational uses with their associated resource impacts.

Unit research has been conducted at numerous sites within the Appalachian Mountains Region, including Great Smoky Mountains and Shenandoah National Parks, New River Gorge National River (and 4 other WV rivers), Delaware Water Gap National Recreation Area, and Upper Delaware Scenic and Recreational River. These studies have involved investigations of tramping impacts to soils and vegetation associated with hiking activities (trail-related), day-use (picnic sites, river rafting), and overnight use (campsites). Over the past two years site visits and management consultations involving 16 high use and impact shelter/camping areas along the Appalachian Trail have been conducted. Case studies have been prepared and research and monitoring to evaluate the effectiveness of implemented management responses will soon be initiated. Similar work is underway at Shenandoah NP to evaluate a new set of camping management options implemented at the park in 2000.

Other relevant unit work includes research and technical assistance in carrying capacity decision frameworks, including identification of prescriptive management objectives, selection of resource indicators and standards, and development of impact monitoring protocols. Limited work has also been conducted to examine visitor impacts to wildlife, including an extensive review of monitoring methods.

Restoration of a Native Brook Trout Fishery to the Upper Shavers Fork, a Large, High-Elevation Watershed in West Virginia

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A series of studies were designed to assess the feasibility of restoring a native brook trout (*Salvelinus fontinalis*) fishery to the upper Shavers Fork in West Virginia. These studies included: basin-wide assessment of water and habitat quality, quantification of stream ecosystem processes along a river continuum, radiotelemetry of brook trout movements and habitat use, spatial structure and dynamics of trout populations in the Shavers Fork mainstem and associated tributaries, and applying habitat selection theory to predict trout population response to watershed management approaches. Our results indicate that the future quality of the fishery is critically dependent on the success of proposed watershed restoration actions, which include limestone additions to acidified tributaries and restructuring of the mainstem channel to increase habitat complexity.

Water Quality in the Coal Mining Areas of the Appalachian Plateau

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Water quality of the surface and ground water in coal mining areas of the Allegheny and Monongahela River Basins (ALMN) was assessed during 1996-98 as part of the National Water Quality Assessment (NAWQA) program of the U. S. Geological Survey.

Although improvements in water quality have resulted from efforts initiated by government agencies, concerned citizens, and coal companies, coal mining remains the largest single factor affecting water quality in a large part of the ALMN. New sources of highly acidic and metal-laden discharges are rarely seen today, but surface and ground water leaving coal mined areas does differ from surface and ground water in unmined areas, particularly constituents such as sulfate. Sulfate yields in 8 mined basins sampled were on average 5 times greater than sulfate yields in 3 unmined basins sampled. Both numbers of fish and number of fish species were greater in unmined basins compared to mined basins. In basins where sulfate was greater than background (about 21 mg/L in ALMN areas that are unmined) aquatic invertebrates showed decreased diversity.

In 1998, a regional assessment to define water quality in coal mining regions of both the ALMN and the Kanawha-New River Basin (KANA) was added to the NAWQA program. The 1998 regional assessment included sampling 178 sites for surface water chemistry, 61 sites for invertebrates, and 83 wells for ground water chemistry. Mined sites were compared to unmined sites. Surface water sites sampled in 1998 were compared to chemistry from the same sites sampled in 1979. The median pH increased and the total iron and total manganese concentrations decreased in mined basins between 1979-81 and 1998, reflecting improved water quality during the last two decades. Dissolved iron, manganese, and aluminum concentrations in mined areas exceeded water quality standards much more often in mined basins than in unmined basins. Sulfate, an unregulated constituent in mined basins also often exceeded sulfate concentrations in unmined basins. Invertebrate communities tended to be more impaired in mined basins than in minimally altered basins and unmined basins. Pollution tolerant species were more likely to be present in mined basins compared to unmined basins, whereas pollution-sensitive taxa were few or absent in heavily mined basins. Both an increased sulfate concentration and a decline in some aquatic insect populations were related to coal production. Ground water from wells located downgradient from surface coal mines that completed reclamation efforts exceeded water quality standards for sulfate, iron, manganese, and aluminum much more frequently than ground water in unmined areas.

Mesohabitat Use of Threatened Hemlock Forests by Breeding Birds of the Delaware Water Gap National Recreation Area

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To assess avian biodiversity, mesohabitat relations, and the risk of loss of species diversity with declining hemlock forests in Appalachian park lands, 80 10-min point counts of breeding birds were conducted in June 2000 on four forest-terrain types previously sampled in the Delaware Water Gap National Recreation Area (DEWA) for aquatic biota: hemlock and hardwood benches and ravines. Point centers were established randomly within sample units, ground truthed with the aid of Global Positioning System technology, and moved if necessary to avoid habitat edge. Point-count radii were limited to 50 m to minimize differential species detection rates, and all counts were conducted between 0530 and 1000 hours in good weather conditions. Mesohabitat sensitivity was calculated as $(D_b - H_b) + (D_r - H_r)$ for forest type and as $(B_d - R_d) + (B_h - R_h)$ for terrain type, where D, H, B, and R are proportion of points where the species occurred in hardwood (deciduous), hemlock, bench, and ravine habitats, respectively, and d, h, b, and r qualify specific mesohabitats.

We found species richness in hemlock stands (means of 24 and 19 in benches and ravines) to be less than that of hardwood stands (35 and 29), with ravines of both forest types generally supporting fewer species than benches. Territories were also denser in hardwood (9.5 and 7.2 per point) than hemlock (5.8 and 4.7) stands, with somewhat lower densities in ravine terrains than benches in each case. Species most sensitive to forest type were black-throated green warbler (*Dendroica virens*), American redstart (*Setophaga ruticilla*), red-eyed vireo (*Vireo olivaceus*), Blackburnian warbler (*Dendroica fusca*), blue-headed vireo (*Vireo solitarius*), Acadian flycatcher (*Empidonax virescens*), scarlet tanager (*Piranga olivacea*), eastern wood-pewee (*Contopus virens*), and wood thrush (*Hylocichla mustelina*), while those most sensitive to terrain type were American redstart, red-eyed vireo, ovenbird (*Seiurus aurocapillus*), blue-headed vireo, veery (*Catharus fuscescens*), and Blackburnian warbler. Of these only four species showed strong preference for hemlock over hardwood habitat: black-throated green warbler, Blackburnian warbler, blue-headed vireo, and Acadian flycatcher. Of these four forest-type specialists, only two, Blackburnian warbler and blue-headed vireo, showed strong preference for a particular terrain type, the ravine mesohabitat. Thus breeding bird data from DEWA forests indicate that four insectivorous neotropical species, Acadian flycatcher, blue-headed vireo, black-throated green warbler, and Blackburnian warbler, are essentially obligate hemlock-associated species at risk should adelgid-mediated hemlock decline continue in park lands and similar forests of the mid-Atlantic east slope. Two of these, the blue-headed vireo and Blackburnian warbler, appear to specialize in ravine mesohabitats of hemlock stands, the vireo a low-to-mid canopy species, the warbler a mid-to-upper canopy forager.

Landscape Determinants of Nonindigenous Fish Invasions

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Much has been written about the influence of exotic or nonindigenous species on natural habitats and communities of organisms, but little is known of the physical or biological conditions that lead to successful invasion of native habitats and communities by exotics. We studied invasivity factors in headwater streams of the Susquehanna River West Branch, which drains portions of the northern Appalachian Plateau. A replicated (two major tributaries) 3 X 3 factorial design was used to determine landscape effects of size (stream order) and quality (land use) on abiotic (physical and chemical) and biotic (fish community structure and function) stream attributes. Seven (21%) of 34 fish species (brown trout, common carp, mimic shiner, bluegill, smallmouth bass, fantail darter, and banded darter) collected in the 18 streams sampled were nonindigenous to the basin. Watershed size (stream orders 1, 3, and 5) significantly affected stream geomorphologic and habitat variables (gradient, width, depth, current velocity, diel water temperature, bank overhang, canopy cover, and woody debris density) but not water-quality variables, while land use in watersheds (conservation, mining, and agriculture) significantly affected measured water-quality variables (alkalinity and concentrations of manganese, calcium, chloride, nitrate, and total dissolved solids) but not stream physical or habitat quality. Both watershed size and land use affected fish-community variables such as presence of particular species, species density, species diversity, tolerance diversity, and mean fish size, but in both cases the effect was transparent to native-origin status of fish species. No relationships were found between occurrence of nonindigenous species in watersheds and trophic structure or functional diversity. Therefore, the hypothesis that reduced species diversity increases vulnerability to nonindigenous species was not supported. However, the spatial variation associated with both water-quality and habitat-quality factors was greater in streams with mixed (those with nonindigenous species) than with exclusively native assemblages. These findings suggest that the mechanism for successful invasion by nonindigenous or exotic species is through change in water or habitat quality associated with human or natural disturbances, such as agriculture and mining activities in watersheds. Biotic factors appear to play no or a lesser role in the invasibility of northern Appalachian lotic systems.

On-Going Wildlife Research in the Southern Appalachians

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Six research projects underway at the USGS Cooperative Fish and Wildlife Research Unit at NC State University are examining questions related to the ecology of birds and salamanders in the southern Appalachians. They are:

Ecology and conservation of Neotropical migrants in the southern Appalachians

This study will serve as the basis of Ph.D. thesis at NC State University. It seeks to develop an ecosystem level approach to understanding the conservation needs of Neotropical migratory birds in the southern Appalachians. Great Smoky Mountains National Park (GRSM) is being established as a control site for comparing trends in the distribution and abundance of forest bird populations compared with those from more disturbed habitats in the southern Appalachians. This study will contribute to an evaluation of the effects of land use practices on the diversity and abundance of these birds at a regional scale. The study will:

1. Produce accurate distribution maps of breeding bird species in the Park.
2. Project how large-scale changes, such as forest tree loss due to exotic diseases, air pollution, climate change, or the invasion of Brown-headed Cowbirds or other exotic species, may affect the breeding bird community.
3. Predict the degree to which site disturbances due to development or management may affect particular breeding bird species.
4. Estimate the importance of the Park as a regional population source for declining bird species.
5. Incorporate project data and protocols into the Park's long-term resource monitoring program.

The effects of landscape pattern, core areas, and forest management practices on avian communities in the southern Appalachians

This will serve as the basis of an M.S. thesis at NC State University. The study expands an on-going avian community study in Great Smoky Mountains National Park (GRSM) to include U.S. Forest Service lands adjacent to the Park. GRSM will be used as a control site to examine breeding populations of forest birds in adjacent, managed forests. Together, these studies seek to develop an ecosystem level approach to understanding the conservation needs of breeding birds in the southern Appalachians. A total of 1,376 independent point locations have been censused for breeding birds. Data are being analyzed to determine the relative importance of local versus landscape scale habitat features in predicting the spatial distribution of different bird species.

Determinants of forest songbird nesting success in the southern Appalachians

This study will serve as the basis of a Ph.D. thesis at NC State University. Analysis of 30 years of North American breeding bird survey data indicates that populations of many species have undergone significant declines over the past decade. Reduced nesting success associated with high rates of nest predation in disturbed forest ecosystems has been identified as a major factor in the decline of these populations. The protected natural areas of the Southern Appalachians provide a unique opportunity to address conservation issues for these birds at an ecosystem level. The study is examining the factors influencing nesting success in forest songbird populations in Great Smoky Mountains National Park and adjacent National Forests and wilderness areas. Results of this research are expected to make a

significant contribution to the conservation and management of forest songbird populations in the southern Appalachians.

Assessing the diversity and habitat associations of salamanders in Great Smoky Mountains National Park

This study will serve as the basis of an M.S. thesis at NC State University. The study is measuring the diversity, abundance, and habitat associations of salamanders in the Mt. LeConte quadrangle of Great Smoky Mountains National Park to determine if existing data and protocols developed for long-term breeding bird and vegetation monitoring can be applied to salamanders. Because the habitat associations of salamanders are not well understood, and because salamanders and birds use their habitats on different temporal and spatial scales, the extent to which monitoring programs for these two groups can compliment one another is currently unknown. While there is considerable interest in the degree to which one group of species can indicate habitat conditions for another, to date the concept has received little critical testing. The study will contribute to the development of salamander population monitoring protocols that can be incorporated into the Park's long term natural resource monitoring program.

Evaluation of salamander habitat associations and population monitoring techniques in Great Smoky Mountains National Park

This study will serve as the basis of a Ph.D. thesis at NC State University. It critically examines the relationship between commonly used amphibian abundance indices and estimated true population size. Salamander population size is estimated using capture-recapture, depletion experiments, and a total removal technique. Results are compared to count data from the relative abundance indices to determine the nature of the relationship between count data and population size, and to establish whether observability remains constant over time and space. Constant observability over both time and space are the two key assumptions that need to be met before count indices can be used to infer changes in salamander populations over time, or differences in abundance between locations or habitats.

Statistical inference from count surveys

This study is a collaboration with Dr. George Farnsworth at the University of Houston and colleagues Jim Nichols, Jim Hines, and John Sauer at the Patuxent Wildlife Research Center. We have developed a removal model to estimate detection probability during point count surveys for breeding birds. The model assumes the main factor influencing detection during point counts is the singing frequency of birds. This method for estimating detectability during point count surveys offers a promising new approach to using count data to address questions of abundance, density, and population trends of birds.

Influence of Water Quality, Stream Gradient, and Flooding on Fish Distributions in the New River Gorge National River

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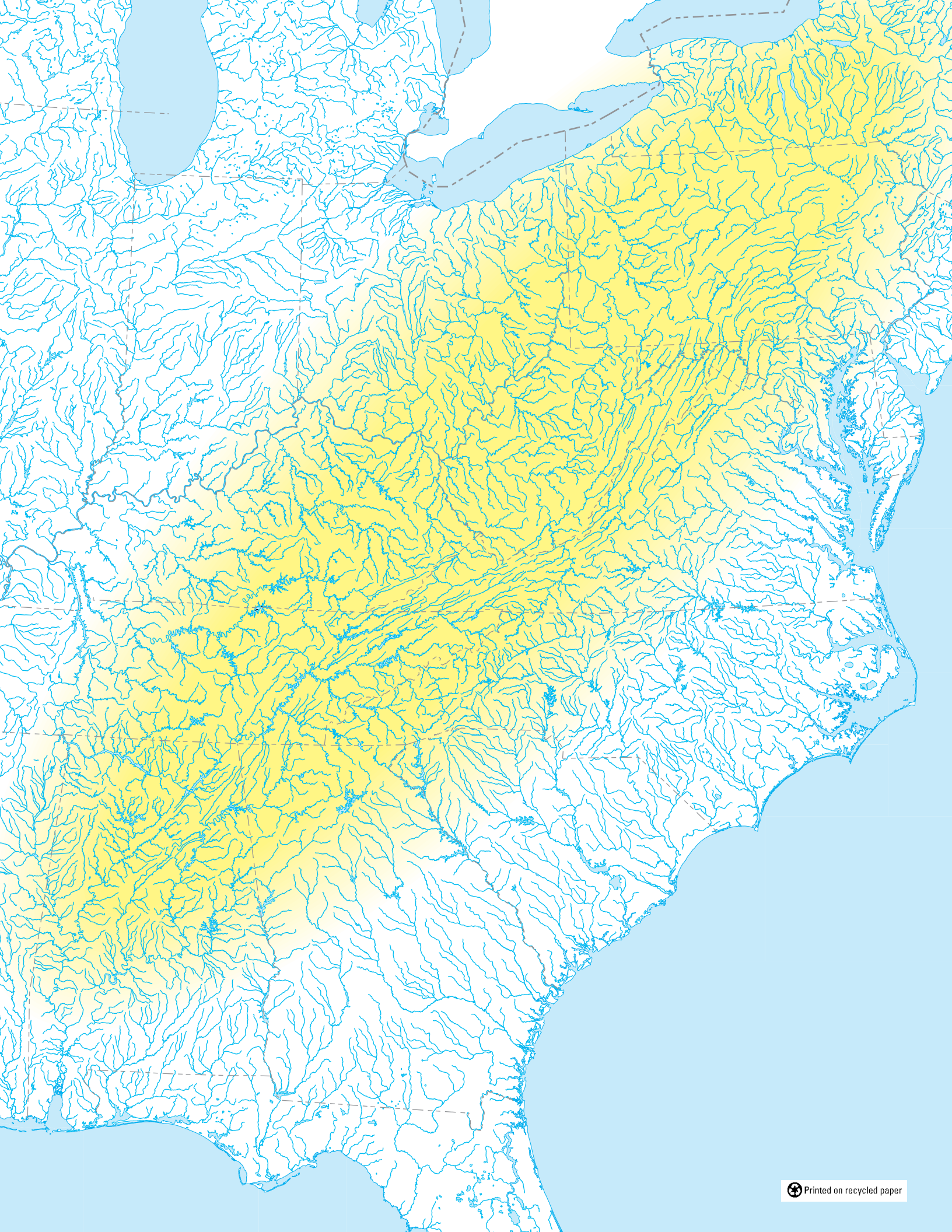
Fish distributions and the species composition of fish communities are influenced by watershed/stream characteristics, catastrophic events, and nonnative species. Currently we are studying the distributions and composition of fishes in the major perennial tributaries of the New River within the New River Gorge National River. Specifically, we are examining watershed/stream characteristics and nonnative species and their association with fish distributions, as well as the affect of recent flood events.



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